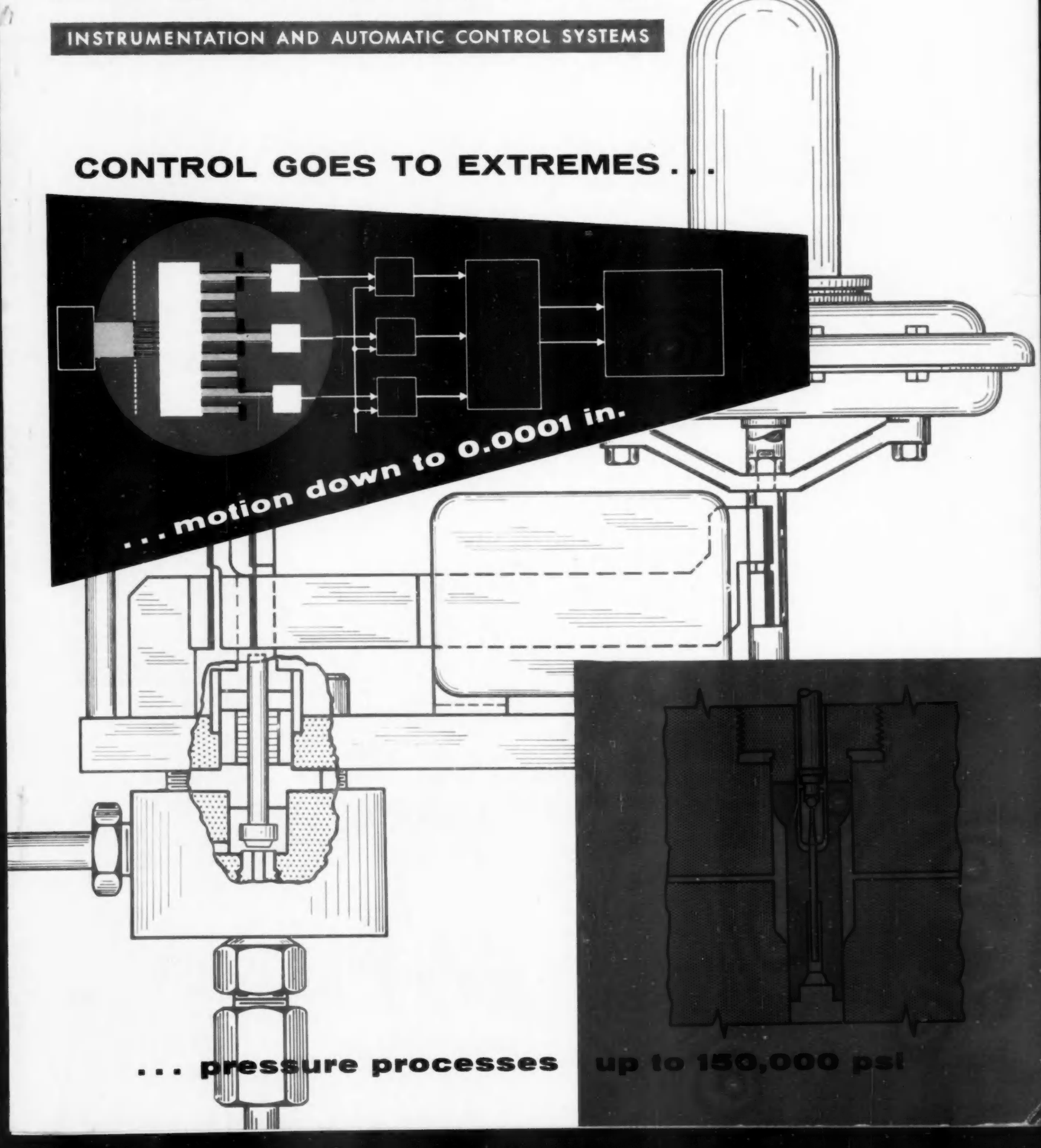
Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

A McGRAW-HILL PUBLICATION

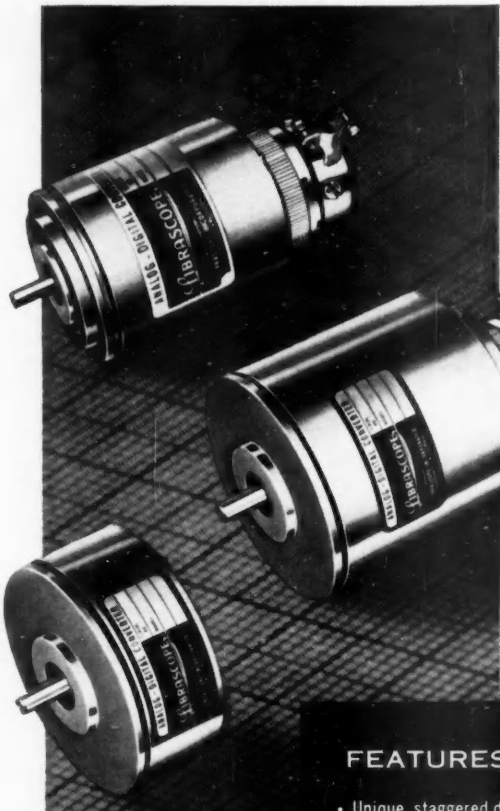
PRICE 50 CENTS

APRIL 1955



Flexibility in Application
Versatility in design...

packaged analog-digital converters



Shaft Position to Digital Converters features reliability, long life, non-ambiguity and speed makes these converters ideal for computers or data handling systems where serial read-out is preferred. Librascope converters transmit information at almost any rate desired up to 1 mc and in some cases above, and may be multiple time-shared, holding extra circuitry to a minimum. All units quickly adjustable, syncro-mounted. Available in Binary, Gray code or Binary decimal code as shown in chart below. Special units may be designed to your order.

Write for catalog information.

FEATURES:

- Unique, staggered double brush pick-off system.
- Reads out serially into relays or single or multiple scan matrices.
- Analog-digital or digital-analog operation.
- May be time-shared.
- Syncro-mounted.
- Associated circuitry can be designed to fit your data-handling problems.

CODE	MODEL*	RESOLUTION PER INPUT SHAFT REV.	RESOLUTION OVER FULL RANGE	DIMENSIONS DIAMETER X LENGTH
BINARY	7 digit	128	1 part in 128	2" x 2 49/64"
	13 digit	128	1 part in 8192	2" x 3 19/32"
	17 digit	128	1 part in 131,072	2" x 4 13/16"
	19 digit	128	1 part in 524,288	2" x 4 13/16"
BINARY CODED DECIMAL	0-2000	200	1 part in 2000	3 1/16" x 4 27/32"
	0-3600	200	1 part in 3600	3 1/16" x 4 27/32"
	0-20,000	200	1 part in 20,000	3 1/16" x 4 27/32"
	0-36,000	200	1 part in 36,000	3 1/16" x 6 3/8"
GRAY	8	256	1 part in 256	3 1/16" x 1 11/16"
*SPECIAL UNITS AVAILABLE	**Precision gearing** **Shaft Speed:** 120 rpm continuous **Operating temp:** —55° C to +75° C **Shock and Vibration:** up to 15 G, 5 to 500 cps.		**Life Expectancy:** Function of lead current. For 13 digit unit @ 2 ma. per brush, life approx. 5×10^9 breaks or makes at approx. 120 rpm.	

Engineers, physicists and mathematicians interested in challenging California careers, contact Mac McKeague, Personnel Director.

LIBRASCOPE

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COMPUTERS, COMPONENTS AND CONTROLS.

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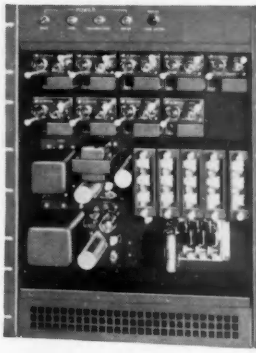
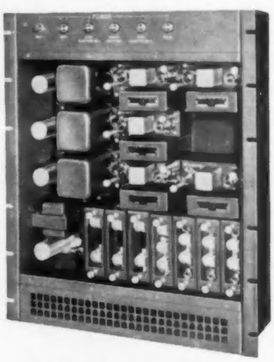
MULTI-GATE*— A Proven Data Transmission "Pipeline"

for CENTRALIZED* OPERATIONS CONTROL



Multi-Gate Transmitter



Multi-Gate Receiver

Control Engineers tell us the most important part of any remote supervisory control system is the "pipeline"—the means by which data is sent from control point "A" to operating point "B". And these same control engineers tell us our MULTI-GATE Systems have proven themselves as compact, efficient, and dependable "pipelines."

The MULTI-GATE system provides complete "on-off" or "raise-lower" control and report-back indication of practically an unlimited number of remote switches for valves, pumps, lights, power transfer and other functions, as well as alarm indication. Pipelines, refineries, chemical plants, railroads, public utilities and many other industries are finding MULTI-GATE an efficient, money-saving tool. All their control operations can be performed over a single communications circuit.

When used with telemetering equipment, *simultaneous control and remote metering* of such quantities as flow, temperature, pressure and electrical quantities are available over the same circuit—radio, microwave, wire or carrier—because all operations are performed by audio tones.

The transmitter and receiver terminals pictured at the right are typical of Hammarlund MULTI-GATE equipment. These units, designed for a 42 function system (21 "on-off" operations), take little space and are readily accessible when mounted in a standard 19-inch rack.

For details write The Hammarlund Manufacturing Co., Inc., 460 West 34th Street, New York 1, N. Y. Ask for Bulletin CC-8

CENTRALIZED* OPERATIONS CONTROL (trademarks pending)

Hammarlund's systems for completely controlling and metering of any number of remote functions from central operation points for efficiency, speed and economy.

HAMMARLUND

Since 1910

Control ENGINEERING

APRIL 1955

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

FEATURE ARTICLES

IDEAS AT WORK

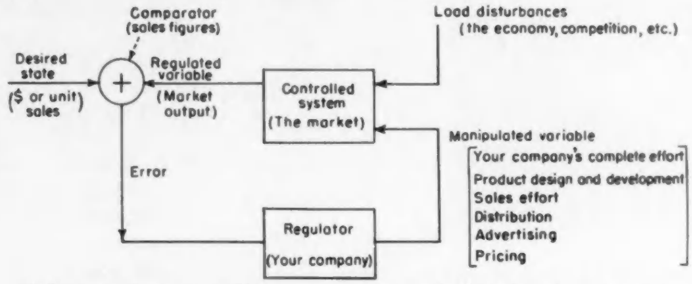
DEPARTMENTS

PRINT ORDER THIS ISSUE 24,596

SHOPTALK

RUSS FINDS FEEDBACK EVERYWHERE

Russ Berg, CONTROL ENGINEERING's ardent New England-New York space salesman, wastes no opportunity to pick the brains of top technical men. Recently, while sipping cocktails in a clubroom overlooking the Charles River, an MIT notable remarked to him: "Feedback applies to every form of human endeavor." That stirred Russ's imagination so much that he hurried back to his hotel room and worked out the following block diagram showing feedback in a generalized business operation:



No wonder our editors sometimes find it hard to keep up with Russ's bustling intellect.

LIKE FATHER, LIKE BRAINCHILD

Editors often get privileged glimpses of the minds of great men. A case in point occurred during Ray Auger's visit last month to Bell Labs. One computer expert there reached in a drawer and whipped out a long strip of paper. "This is an electro-encephalograph," he said. "What do you think of it?" Ray noted that one of the two wavy traces on the paper was very irregular, whereas the other had long straight periods broken by little steps. Still, both had roughly the same amplitude and frequency. "What about them?" he asked. "This line," replied the expert, pointing to the very irregular trace, "is the brain wave of Claude Shannon; the other comes from the machine behind you."

TEXANS AREN'T ACCOMMODATING

As our last issue went to press, Ed Kompass returned from a three-week tour of Texas. He capped his trip by keynoting a session of the Dallas-Fort Worth Section, IRE, sectional meeting in Dallas, which was the first get-together of any IRE Professional Group on Automatic Control. Only once did Texans fail to extend him their famed hospitality. He wrote ahead to reserve a room at the new Statler in Dallas and got this reply: "It is with regret that I inform you that the Hotel Statler...is under construction, and we anticipate completion around October 1 of this year." Didn't even offer to hurry up and finish the building for him.

FEEDBACK

Addendum

To the Editor—

In reference to the article "Where is Electronics Used in Control" in the February 1955 issue, I find that one of the newest and the fastest growing applications of electronic control is omitted, and that is, its use in the Construction Industry.

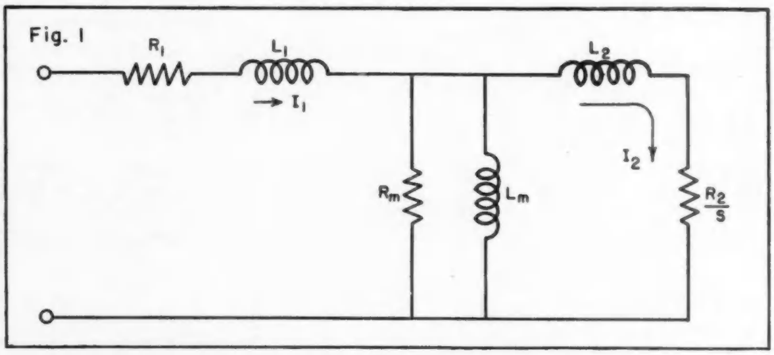
The automation of batching equipment where the various materials used in making concrete are weighed automatically has increased tremendously in the past few years, as evidenced by the number of companies that now make and sell such systems. The need of faster and more accurate batch systems for the sake of economy is becoming more and more apparent to those of us in the industry.

Richard K. Brugler
Warren, Ohio

We shall gladly modify our editorial output in response to such constructive feedback from our readers.—Ed.

PROBLEM FORUM

A group steadily increasing in number beyond 20,000 attends this forum every month. Submit your control engineering problem to their accumulated 150,000 man-years of experience in all the widespread areas of our field. We offer cash for challenging problems and outstanding solutions.



Equivalent circuit of one phase of two-phase inductance motor. Fig. 1

The Situation: DC current is suddenly applied to one phase of a two-phase induction motor

Calculate: The braking

The formula for the torque developed by the motor, derived in texts on ac machinery, is

$$T = m \frac{1352}{N_S} I_2^2 \frac{R_2}{S} \qquad \text{Eq 1}$$

where m = number of phases

R_2 = effective rotor resistance

S = slip $\dfrac{N_S - N}{N_S}$

N_S = synchronous rpm
N = rotor rpm
I_2 = branch current shown in Fig. 1
R_1 = phase resistance
L_1 = phase leakage inductance
R_M = equivalent core loss resistance
L_M = air gap inductance
L_2 = rotor leakage inductance

The absence in the derivation of any

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restriction on frequency means that the dc case can be studied by allowing the frequency to approach zero.

$$N_S = \frac{120f}{P} \qquad \text{Eq 2}$$

where P = number of poles
and f = carrier frequency

$$\text{then} \qquad -S = \frac{120f - PN}{120f}$$

$$\text{and} \qquad \frac{R_2}{S} = \frac{120fR_2}{120f - PN} \qquad \text{Eq 3}$$

which approaches

$$-\frac{120fR_2}{PN} \quad \text{at low frequency.} \qquad \text{Eq 4}$$

This term approaches zero with f. Consequently, the branch containing R_2/S is not short-circuited by L_m, but takes a definite portion of I_1. Then

$$I_2 = \frac{j2\pi fL_M}{-\frac{120fR_2}{PN} + j2\pi f(L_2 + L_M)} I_1 \qquad \text{Eq 5}$$

The power in R_2/S is found for balanced two-phase operation by substituting Equation 5 in Equation 1

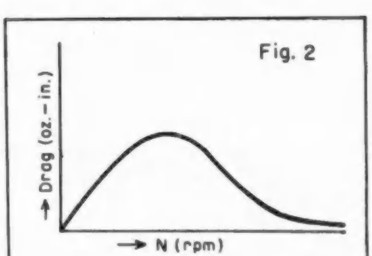
$$|T| = -2704\left\{\frac{(2\pi L_M)^2}{-\left[\frac{120R_2}{PN}\right]^2 + [2\pi(L_2+L_M)]^2}\right\} I_1^2 \frac{R_2}{N} \qquad \text{Eq 6}$$

As the dc current applied to one phase corresponds to the instantaneous ac condition of maximum in-phase current and zero current in the quadrature phase, I_1 must be replaced by

$$\frac{I_{DC}}{\sqrt{2}}.$$

Substituting in Equation 6 and clearing,

$$T = -\frac{1352R_2N\left(\frac{\pi}{60} I_{DC}L_M P\right)^2}{R_2^2 + \left[\frac{\pi}{60} PN(L_2 + L_M)\right]^2}$$



Drag vs speed for two-phase servomotor with dc on one phase. FIG. 2

FEEDBACK

The negative sign indicates that a drag is exerted upon the rotor. Figure 2 shows the relationship between drag and speed.

Sidney A. Davis, Components Div.,
Servomechanisms, Inc.

To the Editor—

In the November [54] issue of Control Engineering a "Feedback Fact" on page 76 certainly deserves a "follow-up." The reaction of fishes to electrical currents of many kinds is being studied at a number of places. The Fish and Wildlife Service has been experimenting with electrical barriers to the sea lamprey in the Great Lakes area. At the Fish and Wildlife Service Laboratory, here in Seattle, we have just completed a large scale test of the use of pulsating direct current for guiding migrant fingerling salmon and are preparing a series of reports, including one on the electrical and electronic devices and circuitry used in our research. Also in preparation is a fishery bulletin on the results of the laboratory work which preceded the field studies. This will summarize the effectiveness of various factors in producing electrotaxis. This response is orientation to, and swimming toward the anode, when an interrupted or pulsating direct current is passed through the water. The parameters were: wave form, pulse repetition rate, pulse duration, voltage gradient, current density, conductivity of the water, water temperature, and fish length.

The data from these various studies show that the problem is very complicated. There are not only differences between species, but within a single specie the lethal voltage, for example, is approximately in inverse proportion to the length of the fish. The kind of current, whether direct, alternation or pulsating; the frequency of the latter two; if the third, the wave form and duration are all significant. It certainly cannot be said to be a "solved" problem and our rather extensive experience has shown that laboratory results must be applied with great caution in the field to prevent occurrence of unfortunate or even disastrous results.

Charles D. Volz
U. S. Dept of the Interior
Seattle, Washington

Volts and dynamite are illegal. And worms are not considered sporting up in northern Maine. —Ed.

A CONTROL PERSONALITY

JACK JOHNSTON
Improves Instrument Application

What is it that holds a man in control engineering work? In the case of Irish-born Jack Johnston, it must be the challenge of new application problems that do not yield to the old tried-and-true solutions. He caught the instrumentation fever while working at Brown Instruments to pay his way toward a degree in mechanical engineering at Drexel Institute. Not cured of the malady after ten years of oil refinery instrument work, he joined F. H. Trapnell's Design Division at DuPont. Demands for new solutions to control problems in existing plants led him to the position of Instrument Consultant in the Engineering Service Division. Solving problems to the satisfaction of often-skeptical plant operators, he soon became Supervisor of Instrument Consultants, a group he has developed to provide a central advisory service in analysis instruments, instrument application, and process automation.

Process Automation Engineers, Carl Sanders, left, and Ted James, right, discuss a control application problem with Jack Johnston, Supervisor of DuPont's Instrument Consultants.

Jack Took a Round Trip from Philadelphia, by Way of Aruba and Argentina

After graduating from Drexel in 1935, he went to work in the Aruba, N.W.I., refinery of a Standard Oil subsidiary. There he realized with a shock that he knew nothing about instruments, even after inspecting and testing them for seven years at Brown. He admits that this rude experience occurred repeatedly in his progress to more responsible work at a Campana, Argentina, refinery and at the Marcus Hook refinery of Sun Oil Co.

Jack and his wife were married twice in Argentina —once in a civil ceremony conducted in Spanish and again in the Episcopal Church, where his wife knew what she was saying. After an illness in the States, Argentina seemed far away, so they settled in Drexel Hill, Pa., and were joined by a son in 1940. Always the make-do instrument man, Jack directed five neighbors in hooking up a two-way communication system with microphones at each baby's crib.

Anyone Should Know That Instruments Don't Run on Sulphuric Acid

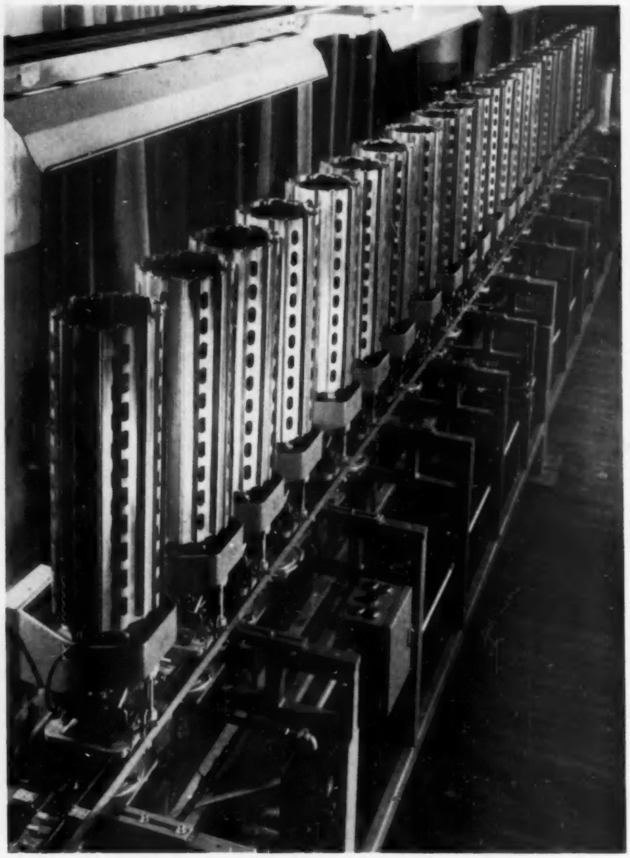
The Campana refinery, although small, featured every phase of the petroleum business. The controllers, among the best of the time, were mares' nests of capillary tubing, multiple bellows, and pneumatic pilots. A maintenance crew that could not read instruction books written in English once demonstrated complete mastery of their trade by getting sulphuric acid in the instrument supply air. This shut down the refinery. But a Pan-American exchange of Spanish and Irish-American swear words soon got the refinery back on stream.

Participating in the beginnings of the Philadelphia Section of the ISA, Jack was president of the section in 1946. He is an active member of ISA's Maintenance and Operations Committee, ASME's and ASA's Terminology Committees (on automatic control), and he is a member of the National Society of Professional Engineers.

A busy man, but one who knows the value of relaxation, he spends his spare time refurbishing an old summer home in Stone Harbor, N. J., and building a 14-ft kit-boat for use there.

Cookie Cartons Create Computers

General Mills' know-how in automatic food packaging is responsible for a machine that brings computer speed to computer production



Wafers run down this line . . .

When Tom James turned his electro-mechanical design talent to problems of high-speed packaging, he had no idea what he was getting into. Somehow, dealing in quirks of carton machines suggested straightening the kinks in computers. So instead of packaging edibles, Tom began designing incredibles.

As in his cookie days, Tom still works for General Mills, where he is now chief of engineering research and development. Engineer James had a big hand in pacing his company's package output to a voracious public—a mechanical genius that attracted complex military hardware contracts to GM during World War II and has carried packaging-machine analogies into a whole line of automatic devices.

The latest General Mills creation is like a page out of Norbert Weiner. It's the first automatic machine for wedding components to printed circuits. And to top it off, the machine will get its shakedown in IBM's production line to speed computers to another customer—the USAF.

MORE PROCESS THAN MACHINE

Actually, the "Autofab" machine, as GM calls it, acts more like a complete process than a machine operation. As the picture shows, it consists of a row of bins which feed component parts to attaching heads operating over a wafer-carrying belt. The close-up view reveals how the assorted resistors, capacitors, pulse transformers, and diodes find their places on the printed circuit. Precise location of each component is a function of the conveyor and a fail-safe arrangement prevents circuit "bloopers."

In operation the printed circuit feeder is loaded to capacity with 400 base plates and each of the heads filled with an average of 600 magazine-oriented components. All the attaching heads, controlled by a cam shaft, operate simultaneously. As each printed circuit positions under a head, the conveyor briefly stops and the component is attached. This continues down the full line of heads until the complete circuit is built.

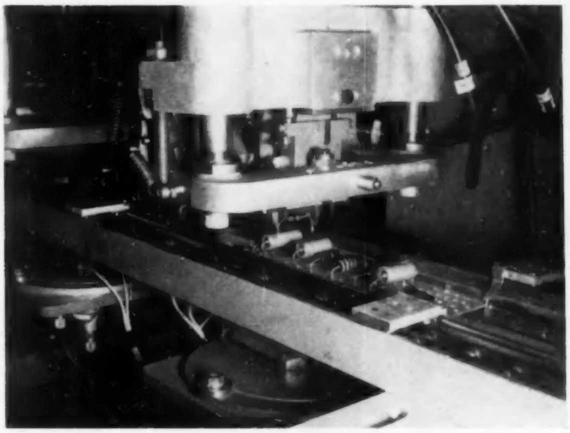
Loss of operating time is eliminated by use of multiple magazine on the base plate feeder and attaching heads. A fresh magazine is automatically cut in as each is depleted. So empties can be filled while the machine runs.

"Autofab" is the first commercially-available unit in what General Mills will call its Electronic Assembly System. The system consists of six fluidly-related steps that will automatically prepare circuit wafers, route and solder components, test and classify, and finally coat each completed unit before it slides from the line. And all this will happen at 20 circuits per minute, or 1,200 assembled boards per hour.

As things now stand, "Autofab" is available in a 12-head unit section for an estimated price of $75,000. Wafer sizes from 2 in. to 10 in. in either dimension can be handled. Component parts from the smallest miniature up to almost an inch in length and diameter are accommodated.

GM engineers are not content to let "Autofab" rest on its present technical laurels. They are already at work on electronic adjustments to obsolete the

Tom James peers while Dr. Cledo Brunetti, Director of General Mills' ERD, points out a fabulous feature of "Autofab"



. . . where components snap in place . . .

. . . to fill quickly a computer's skeleton

manual setting of machine heads. Further, they envision modifications which would let the unit insert conventional tubes into predesigned plates of metallized plastic or fiber for radio and TV chassis.

The two "Autofab" sections going to IBM will produce circuit subassemblies for U. S. Air Force defense computers. Each of these huge digital units requires thousands of circuit building blocks, and IBM is quick to admit that it would never begin to meet delivery dates without General Mills' incredible machine.

For a Smooth Blast-Off Into the Wild Blue

Pilots assigned to taking off jet fighters from truck tops received assuring news. They can now relax as passengers while their planes ascend amid smoke and flame, for their standard autopilots will safely guide them up. The plane makes its zero-length take-off with the aid of a raft of booster rockets. This technique was developed to launch Matador guided missiles from truck-based platforms. When Martin tried the trick on an F-84G, it was discovered that a standard Lear F-5 autopilot could do the job of guiding the plane up despite the severe accelerations, and perhaps do it smoother than the test pilot could.

Vannevar Bush Calls for Automatic Encyclopedia

Dr. Vannevar Bush wants knowledge at his fingertips—all human knowledge. In fact, he wants the Federal Government to start planning the world's most grandiose data-processing project. He would have the mounting volume of human knowledge coded and made available "in prompt, accurate, effective fashion, and at a distance if this is desired."

He made this bold suggestion at a meeting of the ASME, which had just awarded him honorary membership. Only about 150 such members have been named since the society was founded in 1880.

Bush pointed out that equipment is at hand to do the job. Scanners can glance at a thousand items per second. Photographic methods cram a thousand books into the space of a cigarette package. Digital computers manipulate records at the rate of a million numbers per second.

"Our libraries are overflowing," he warned, "and their growth is exponential," with much valuable data embedded in the mass of paper. Breaking loose this mired information would open the way to "another spurt forward of civilization."

MORE DATA HANDLING

Computes Gas Network

Both analog and digital computers are working at the Armour Research Foundation on Northern Illinois Gas

Co's distribution and scheduling problems. The gas company must estimate in advance the winter peak demands and decide whether their networks can deliver the fuel at a satisfactory pressure, computer center supervisor David Rubinfien explains. After the networks are simulated in the computer, electronic brainpower calculates flows and pressure drops. Then the engineers can tell whether and where their system must be boosted.

Saab Orders a Besk

The first Swedish industry to acquire an electronic computer will be Saab Aircraft Corp. The Stockholm firm has just ordered a Besk from the state Mathematic Machines Board. Swedish engineers are proud of this computer, which they claim to be the fastest and most efficient electronic parallel machine of its size.

Saab has just been through a trying stint of calculating—some 2.5 million computations involved in designing their newest jet fighter, the Lansen. This was seven times the volume of numerical work required by propeller-driven models of a decade ago.

The new Besk is supposed to get a novel recording system. A picture tube, now in the design stage, will project results as curves on a screen, as an alternative to pounding out tables on an electric typewriter.

Supervises Pushbuttons

IBM demonstrated a new "electronic supervisor" that turns on and off as many as 40 groups of remote operations to a preset program. Able to open and close valves, start or stop motors, control air conditioning, or blow factory whistles, it would make an efficient office or plant manager.

Important Moves By Key People

►**G. Lupton Broomell, Jr.**, has been promoted to chief engineer of Leeds & Northrup Co. After joining the company in 1937, he rose to head of the recorder development section and later to assistant chief engineer. He is well known in technical society circles for his leadership in electrical instrumentation and control.

►**Joseph P. Green** is now director of engineering for The Swarthout Co. Prior to his arrival at Swarthout two years ago, he was chief instrument

Broomell moves up to L&N chief engineer

Green heads Swarthout engineering

Lynch becomes president of Brush

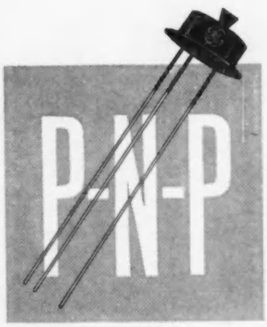
IBM names Schnackel vice-president

Kuhnel has been promoted by Austin

Brand is new Conoflow vice-president

G.E. MECHANIZED PRODUCTION AT LOWER COST...ASSURES

Both types offer high reliability at temperatures



TYPE 2N43A

Take a close look at the transistor values G.E. now offers. Because production lines are now mechanized, these transistors are made in *less time* at *reduced cost.* Machine methods today assure strictest adherence to the top quality standards demanded of all General Electric Germanium Products.

Mechanization results in CONTROLLED CHARACTERISTICS, removing any inaccuracy on the part of the operator. Narrow limits are built into production transistors giving a more uniform product.

In military and commercial applications these G-E transistors offer precision quality, topmost reliability at mass-volume prices!

General Electric's P-N-P junction transistor, 2N43A, is the first to be written into Air Force specifications! MIL-T-25096 (USAF) was actually written around this G-E product which was developed for the military. Now it serves an ever-increasing number of commercial as well as military applications.

APPLICATIONS AND SPECIFICATIONS

TYPICAL USES: Audio and Intercom Amplifiers, Servo Amplifiers, Carrier Current Amplifiers, Test Equipment, Fuel Gauges.

SPECIFICATIONS OF THE 2N43A and USAF 2N43A

Absolute Maximum Ratings:

Collector Voltage (Referred to base)	−45 volts
Collector Current	−50 ma
Collector Dissipation	150 mw
Storage Temperature	100° C
Collector Cutoff Current (−45 volts)	−10 microamps

DESIGN FEATURES:

STURDY CONSTRUCTION... meets critical military tests for shock, vibration, humidity, life.

SEALED JUNCTION... contamination gases permanently eliminated!

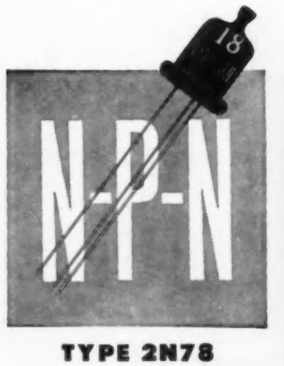
HIGH POWER OUTPUT... case design makes possible a collector dissipation of 150 mw.

HERMETIC SEAL... unaffected by moisture.

LONG LIFE... no change in characteristics during life of equipment.

MAKES TRANSISTORS AVAILABLE CONTROLLED CHARACTERISTICS

up to 100°C...are now available in production lots!



HIGH FREQUENCY TRANSISTOR

A new, revolutionary manufacturing technique, the exclusive G-E rate-growing process, coupled with the all-welded hermetic seal, now makes possible extra long life, and noticeably-reduced manufacturing costs by—

- Making 2000 or more transistors from one rate-grown crystal.
- Achieving uniform characteristics in all 2000 transistors—*eliminating wasteful rejects.*

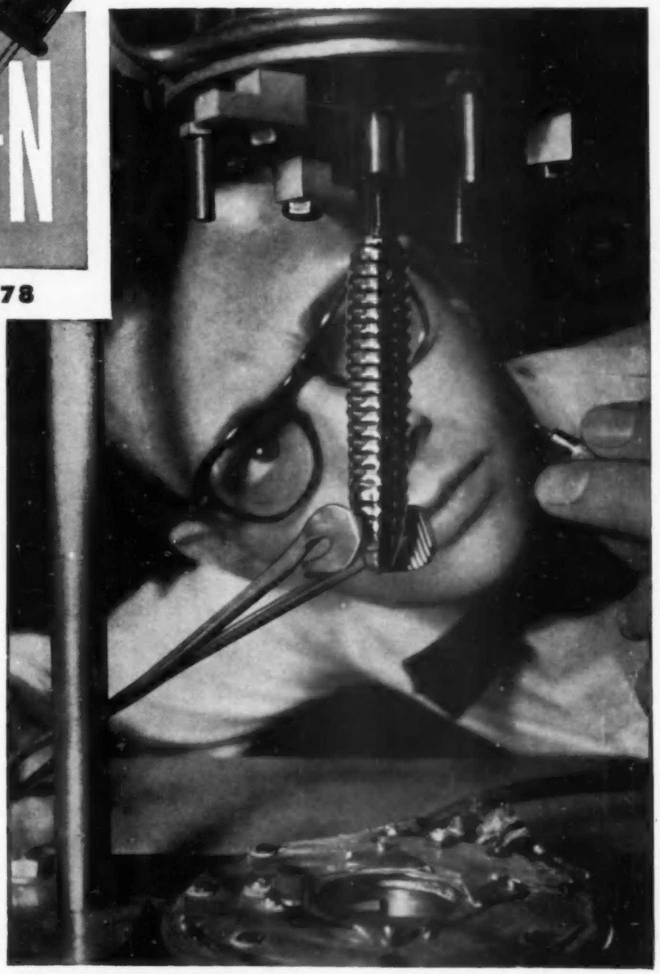
APPLICATIONS

For pulse and switching circuits, RF and IF amplifiers; high-frequency test equipment; telephone repeaters.

SPECIFICATIONS

Collector Voltage (Referred to Base)	15 V
Collector Current	20 ma
Emitter Current	−20 ma
Storage Temperature	100° C.
High Frequency Gain at 2 mc	13 db

- For further details on specifications and prices, write *General Electric Co., Section X9945, Germanium Products, Electronics Park, Syracuse, N. Y.*



Billet of germanium is removed from furnace, prior to cutting into enough tiny pellets for 2000 transistors.

Progress Is Our Most Important Product

GENERAL ELECTRIC

engineer with the H. K. Ferguson Co.

▶ IBM has a new vice-president in charge of manufacturing. He is **Jay W. Schnackel,** previously general manager of the Endicott N. Y., plant. His successor there is **Arthur L. Becker.**

▶ Conoflow has made **Warren H. Brand** vice-president in charge of engineering. Coming to Conoflow less than a year ago, Brand brought with him advanced ideas developed as supervising engineer of the Industrial Instruments Engineering Section at Oak Ridge National Laboratories.

▶ **Douglas C. Lynch** is now president of Brush Electronics Co. He joined the Cleveland company in 1952 after having headed international operations for the Crosley Div. of Avco Mfg. Corp.

▶ Consolidated Engineering Corp. announces two key staff appointments. **Francis T. Greenup** transfers from Vitro Corp. of America to be Consolidated's chief design engineer. And **Jack K. Walker,** manager of the firm's analytical instrumentation group, moves to the System Div. as project chief for process control systems.

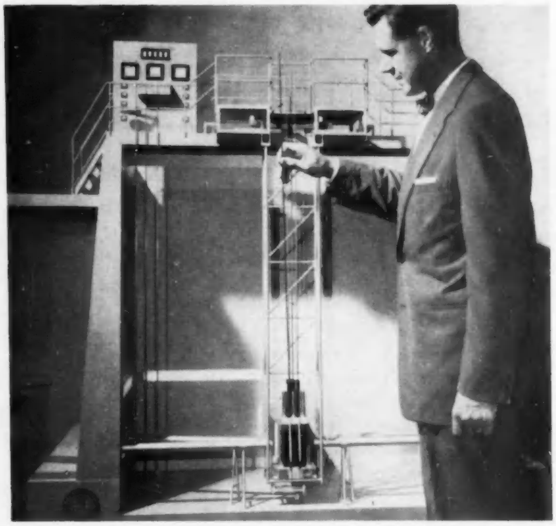
▶ Former AEC chairman **Gordon Dean** is a newly elected director of Ketay Instrument Corp. He has been board chairman of the company's affiliate Nuclear Science and Engineering Corp.

▶ **Alexander H. Kuhnel** has been promoted to assistant manager of The Austin Co.'s Special Devices Div. He will continue to be division engineer.

▶ **David Rubinfien** has been named a senior scientist by the Armour Research Foundation. Rubinfien, one of CONTROL ENGINEERING's consulting editors, has supervised mathematical services in the ARF Electrical Engineering Research Dept. His new job is intended to free him from super-

(continued page 22)

AMF First with Research Reactor for Private Industry



Arthur V. Peterson, Director of AMF's atomic energy division, hoists a control rod in model of reactor which will soon be privately owned and run.

Spurred on by the AEC, American Machine & Foundry has solved the dilemma of how to get private industry to buy an atomic reactor.

As the bars went down on fissionable material and reactor know-how, many construction projects were optimistically planned by industry. But when the figures were assembled, few could buy. A modest-sized reactor could run to $1 million or more. Only endowed institutions such as Washington State College, MIT, and Argonne could afford the tab.

AEC was concerned. It saw great reward in reactor research by aggressive private firms and a speeding of plans for industrializing atomic energy. A strong plea was made that at least one private industrial group pool its resources and set up a test reactor.

Alert management at AMF was ready for the challenge. Capitalizing on the company's past experience in the atomic energy program, a "packaged" swimming pool reactor was designed, complete with integrated automatic controls and unitized construction. Early this year a proposition was made to a group of interested manufacturers: cost of the reactor facility would be spread among all participants and AMF itself would take part in its operation. The project was bought.

A 250-acre site near New York City is planned for the cooperative reactor. Its fuel will come from the AEC on a license-fee basis. Its operation also will be licensed by the AEC, much as a steam plant is licensed by law. Estimates are that the new reactor will be ready by the summer of 1956.

AMF board vice-chairman General Walter Bedell Smith looks for grand results from the new facility. "We strongly believe," he predicts, "that many yet-unknown benefits of atomic energy will be brought to light more quickly in private research. We envision the development of new and important commercial products and improvement of a great number of industrial processes."

Judging from the variety in participating companies, the reactor will be put to wide and flexible use. In the group are representative firms from the food, chemical, petroleum, ceramics, metals, machinery, and electronics manufacturing industries.

Control engineers will be especially intrigued with two aspects of this first commercial test reactor. They will surely scrutinize its automatic controls—particularly since these will include most of the elements described by Seymour Oestreicher in his article on pp 83-84 of September 1954 CONTROL ENGINEERING. Also, with an electronics manufacturer in the act, the reactor will find some concerted use in exploring and developing new ways and means for radiation techniques in measurement and control.

visory tasks and give him more time for creative thinking.

▶ Marion Electrical Instrument Co. has named **F. J. Gaffney** vice-president for engineering. After heading the test and measurements group at the MIT Radiation Laboratory during the war, Gaffney was general manager of the Polytechnic Research and Development Co. from 1945 until 1953, when he joined Marion.

▶ **Melvin L. Jackson** comes to CGS Laboratories, Inc., as vice-president. For nine years he has been with Airborne Instruments Laboratory, most recently as manager of the contract office.

▶ **John Pamperin** is the new production manager of Helipot Corp.

Texas Meetings Explore Frontiers

When Texans overrun frontiers in one direction, they open them up in another.

This truism was emphasized at the IRE's Southwestern Conference and Electronics Show, held in Dallas Feb. 10-12 by the institute's Dallas-Fort Worth Section. Pioneering as usual, the section's Professional Group Chapter on Automatic Control scooped the national group with the first technical session on the subject since the PGAC was formed last October.

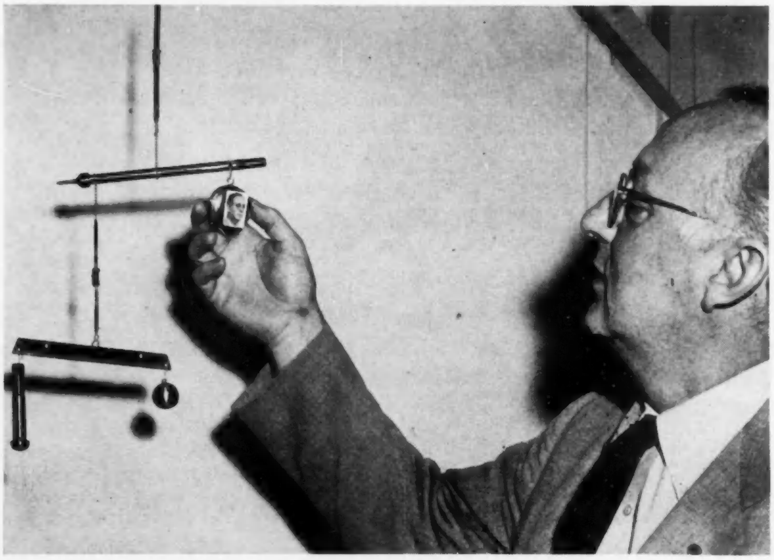
Control Engineering was represented by assistant editor Ed Kompass, who keynoted the session, haranguing the electronics experts in the vein of this month's editorial (see page 43).

For a regional meeting, this one was just normal for Texas—this is to say, stupendous. Seventy-five exhibitors showed everything from wire to computers. And 1,100 engineers paid for the privilege of shouldering in for a look.

At that, the Dallas IRE meeting only scarcely outstripped Texas A&M's Tenth Annual Symposium on Instrumentation for the Process Industries, held two weeks earlier at College Station. Some 350 paying customers were lured to the beautiful Memorial Student Center. Although the meeting was meant primarily for instrument men of the Gulf Coast's petrochemical industries, 15 per cent of the engineers had come more than 1,000 miles to hear technical papers and mill around 50 or so instrument exhibits.

Electronic controllers, continuous analyzers, and dry instrument air all got their due from manufacturers and users at this unique nuts-and-bolts conclave, as did more complex subjects such as the dynamic response of flowmeters. Among the speakers, Wilfred H. Howe of Foxboro rounded up high-pressure instrumentation, as he has done in this issue (page 53).

Porter Hart, instrument shop superintendent of Dow Chemical's Texas Div. at Freeport, was elected to the elite group of Screwballs—comprising instrument men who have evolved special and unusual devices for process control. The 1954 Screwball, A. A. Anderson of Carbide and Carbon, Texas City, designed Hart's award, (see cut), a unique mobile symbolic of something or other. Next year Hart will have to design a similarly fitting trophy for the 1956 Screwball.



Porter Hart of Dow Chemical, newly elected Screwball, ponders his award

IRD, ASME Schedules Control Conference

The University of Michigan will be the scene of a two-day (April 25-26) conference on automatic control, sponsored by the ASME's Instruments and Regulators Division.

Chairman will be Prof. John Hrones of MIT, who promises an outstanding series of papers emphasizing basic dynamics of control rather than mathematical methods of solution. Key areas to be covered include: the control of physical systems, physical systems with a human operator, and business and economic systems.

Diamonds and Gold—Stake Em or Make Em

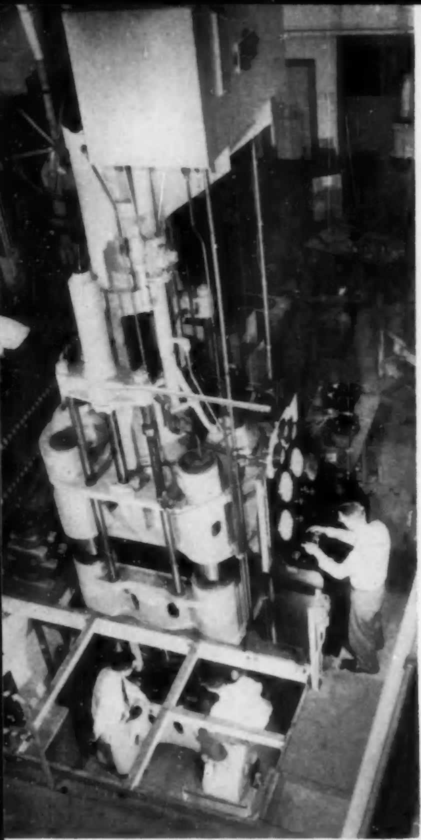
As the man says, if you engineers keep plying your technology it's no wonder a buck's not a buck anymore.

Take diamonds. Used to be that an engagement ring was worth two years for Junior in college. But who can tell now. GE's has a press that puts 1.6 million pounds pressure on a square inch of carbon. And what do you have? Diamonds.

The same holds true for gold. Some sly reactor work and transmutation can take place. And lately, a scintillometer has been used to ferret out gold and even diamonds. If you can't make it, it will be easy to stake it.

True, GE did produce a diamond from carbonaceous material under some staggering man-made pressure and temperature. But the cost of exerting these special forces and the miniscule production hardly suggest a dent in the diamond market. Further, the man-made diamond is notably lacking in gemlike qualities. It is more likely that the GE process will be used to produce industrial diamonds for cutting and polishing.

Use of the scintillometer for gold and diamond hunting also has its qualifications. Its function here depends on what scientists call the "radioactivity anomalies" technique. It appears that minute traces of



If you want to make diamonds set up this 1,000-ton press—but you'll probably have to consult with GE Research to duplicate its achievement

uranium are often associated, in nature, with primary deposits of rare minerals. So if the scintillometer ticks faintly you may have gold. But you still have the arduous job of digging and panning to prove the theory.

Around The Business Loop

▶ **Elgin National Watch Co.,** moving further into the field of miniature electronic components, has just bought up **American Microphone Co.,** Pasadena manufacturer of microphones, phonograph pickups and cartridges, and related items. The new acquisition will become a division of Elgin-Neomatic, Inc., formed less than four months earlier.

▶ **American Machine & Foundry Co.** stepped into the oil business with the purchase of **American Iron & Machine Works Co.** The new Oklahoma City subsidiary is a manufacturer of oil field drilling and recovery equipment.

▶ **Topp Industries, Inc.,** has enlarged its line of precision potentiometers with the acquisition of **Standard Electronic Mfg.** With its added facilities and expert personnel, Topp will now offer a special design service on unusual requirements.

▶ **Fischer & Porter** is turning to streamlined construction for a new 4,000-sq-ft building in Hatboro, Pa. It will be built by the Youtz-Slick lift-slab method. After the concrete floor is cured, the reinforced concrete ceiling is poured directly on top of it. Then the ceiling is hydraulically jacked into place.

▶ **Robertshaw-Fulton Controls Co.** has opened a more conservatively built structure in Long Beach, Calif. The 237,000-sq-ft plant will house the new Grayson Controls Div., which will double R-F's production of thermostatic controls and ignition devices for gas heating.

▶ **International Business Machines Corp.** announces plans for two new buildings at Poughkeepsie, N. Y. Adjacent to the IBM Research Laboratory, the new facilities will be used for engineering and development of electronic data-processing equipment.

▶ **ElectroData** will more than double its production capacity with a new 40,000-sq-ft Pasadena headquarters building. An unusual feature will be a demonstration computing center enclosed by glass walls and visible from the lobby.

▶ The **Barry Corp.** of Watertown, Mass., has taken on a more descriptive name: **Barry Controls, Inc.**

Michigan Summer Course Elucidates Computers

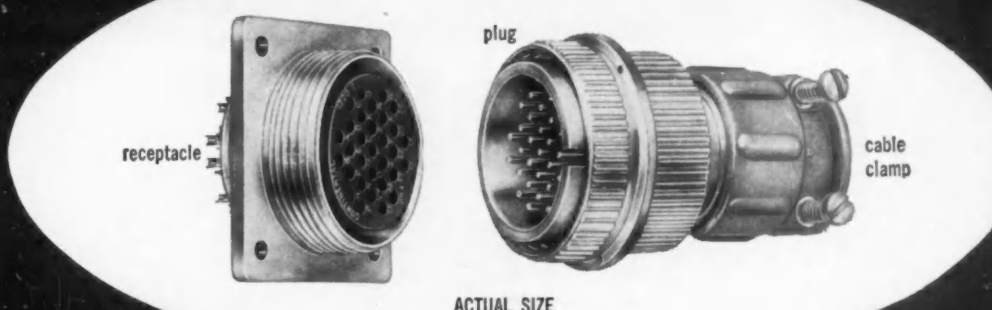
The University of Michigan announces an expanded two-week summer course on computers, Aug. 1-12. The program will impart an understanding of present-day computers and an idea of their potential applications. As part of the course, users will report directly on how their computers behave and will attempt to evaluate objectively manufacturer's claims.

Basic parts of the course, which will be taught at both elementary and advanced levels, are the structure of digital computer systems and formulation and programming. Beyond this point, the classes will divide according to special interests: engineering and logical design, business data processing, or scientific and engineering computations. The major laboratory tool will be MIDAC, the university's big fast general purpose digital machine. And after the two weeks are over, students will get a 500-page bound volume of course notes to take home and ponder at their leisure.

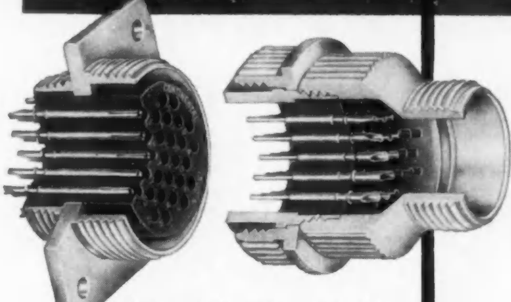
The cost is $160, plus room, board, and incidentals. For complete information and application blanks, write directly to Dr. John W. Carr, Willow Run Research Center, University of Michigan, Ypsilanti, Mich.

Fischer & Porter raises the roof at Hatboro, Pa., while Robertshaw-Fulton opens new Long Beach plant for its Grayson Controls Div.

new...precision Continental Connectors



miniature AN-type



Cut-away view shows precision construction of Continental Series 1300

CONTACTS FOR #20 AWG WIRE

NO. OF CONTACTS	SHELL SIZE
4 and 5	$^{9}/_{16}$ -24
15, 19, 27 and 31	$1^{3}/_{16}$ -18

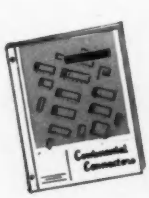
If you have been looking for a dependable, miniaturized version of the popular A N-type connector, then consider this new Continental Connector Series 1300.

Two small shell sizes accommodate several contact arrangements. The shells are precision machined aluminum, threaded for use with conventional cable clamps. Brass pin contacts and spring temper phosphor bronze female contacts are gold plated for easier soldering —pre-tinning of solder cups is unnecessary. Each contact is individually floating, to assure self-alignment and reduced engagement forces.

One-piece molded inserts prevent moisture traps and possible electrical breakdown. They can be interchanged between the plug and receptacle shells for greater versatility. Our standard molding compound is Mineral filled Melamine (MIL-P-14D, Type MME). However, other compounds are available on order.

Write to our sales engineering department for technical data on the Series 1300, PLUS other special designs and circuit applications requiring the use of sub-miniature, printed circuit, hermetic seal, pressurized, high voltage or power connectors.

JUST OFF THE PRESS!



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Current ratings up to 25 amp, AC or DC

When you want the utmost in relay dependability, investigate the Amrecon line. Amrecon relays are designed, produced, and tested in the new, air-conditioned Ohmite plant.

These ruggedly built relays have the ability to handle power loads usually requiring larger, heavier units. They are built to meet rigorous aircraft relay standards, and are particularly adapted to mobile equipment where severe shock and vibration are encountered.

Amrecon relays are available with screw, plug, or solder-wire terminals; in a variety of contact arrangements; with hermetically sealed or dust-protective enclosures. Order from the 30 stock types, or let Amrecon's engineers help you work out special relay applications.

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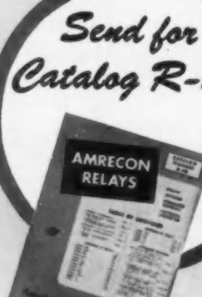

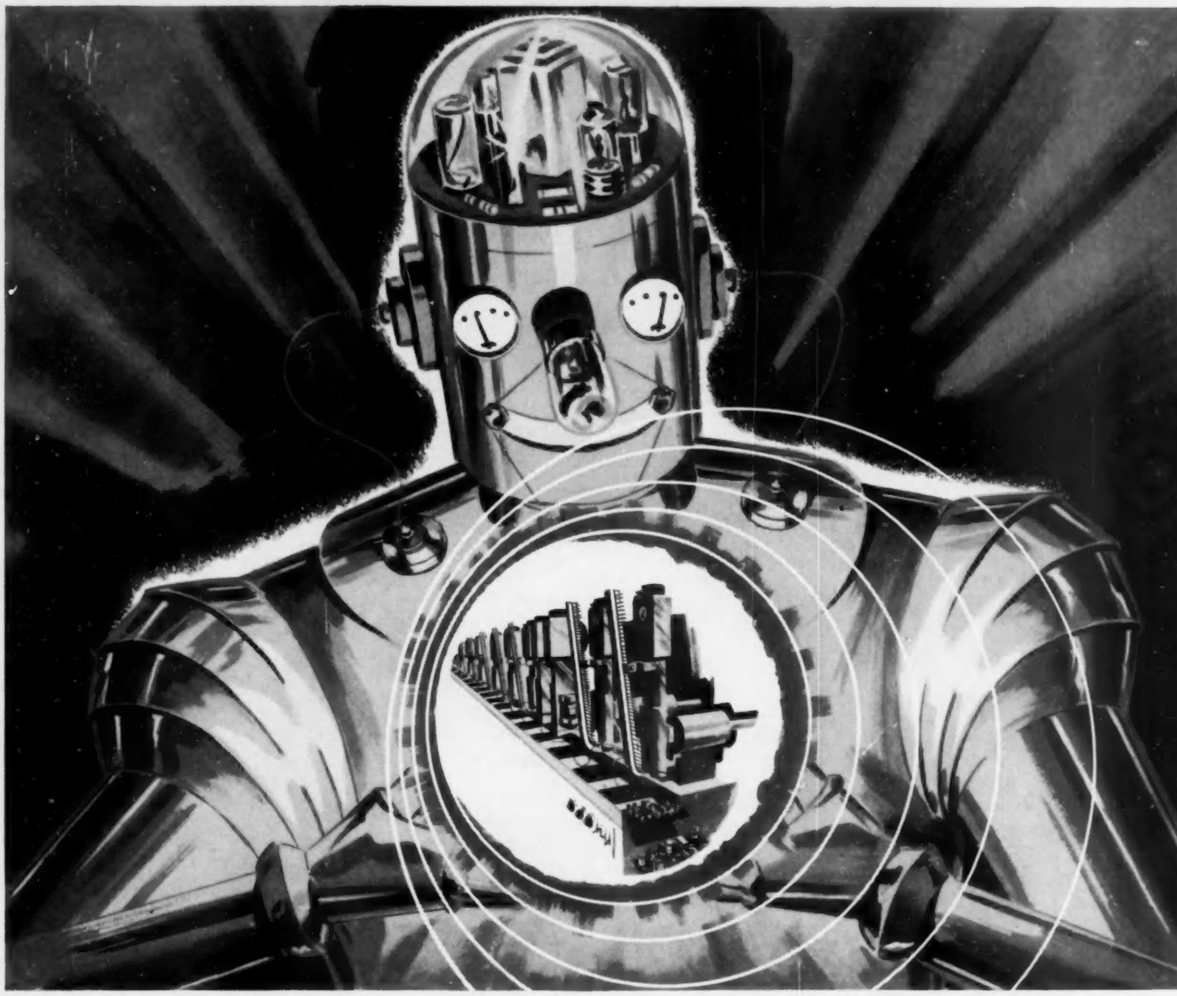

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1 **Versatility**—A potentiometer to meet a wide field of applications without additional design changes.

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3 **Long Life**—Rigid, fixed lead screw to guide contact over resistance element.

4 **Dependability**—A potentiometer that possesses excellent mechanical and electrical stability under extreme environmental conditions.

5 **Absolute Linearity**—A potentiometer with linearity built into it. I don't want to hunt for linearity by trimming.

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7 **Availability**—I want the model that fits my needs readily available in production quantities.

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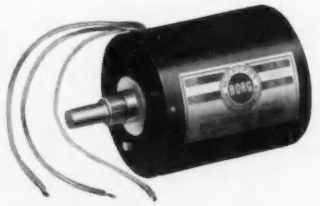
A precision 10-turn potentiometer that offers your products a price advantage in today's competitive markets. Engineered for easy installation with 9 inch coded leads. Accurate, dependable, long lived.



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BORG EQUIPMENT DIVISION
THE GEORGE W. BORG CORPORATION
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Typical characteristics of some of the unit

400 and 60 cycle Servo Motors. High torque to inertia servos are available as small as a penny and up to Size 23. Torques of 0.1 in. – oz. to 7.5 in. – oz.

TWO PHASE SERVO MOTORS

TYPE NO.	GOVT. DESIG-NATION	FRAME SIZE	FREQUENCY	MIN. TORQUE AT STALL (IN OZ.)	NO LOAD SPEED (MIN.)	POWER PHASE AT STALL (WATTS)	NO. OF POLES	RATED VOLTAGE FIXED PHASE	RATED VOLTAGE CONTROL SERIES	EXCITATION PHASE PARALLEL
K402390		10	400	.3	6500	3.1	6	26	26 (1)	
K402350		10	400	.13	9800	3	4	18	18 (1)	
K402300	MK 14 MOD 2	11	400	.60	6200	3.5	6	115	115	57.5
K402370	MK 14 MOD 3	14	400	.63	6200	4.6	6	115	180	90
K101600-6	MK 7 MOD 0	15	400	1.45	4800	6.1	8	115	115	57.5
K101660	MK 7 MOD 1	15	400	1.45	4800	6.1	8	115	115	57.5
K101650-5	MK 7 MOD 2	15	400	1.45	4800	6.1	8	115	230	115
K402150		15	400	1.3	6200	6.1	6	115	26*(1)	
K101720		15	400	1.4	5000	7		115	115	57.5
K402470		15	60	1.3	1600	6.1	4	24	24*(1)	
K402380		15	60	1.45	3200	6.1	2	115	115	57.5
K402560-1	MK 8 MOD 2	18	400	2.35	4800	9.2/9.5	8	115	282	141
K402550-1	MK 8 MOD 0	18	400	2.35	4800	9.1	8	115	115	57.5
K101780		18	400	1.4	9800	9/8	4	115	115*(1)	
K402550-2	MK 8 MOD 1	18	400	2.35	4800	9.1	8	115	115	57.5
K402600		18	400	1.8	9800	18/8	4	115	115	57.5
113E1Y		23	60	7	3300	16	2	115	115	57.5
113E1Y1		23	60	7	3300	16	2	115	230	115

*(1) Control phase having only one winding.

(1) Also for 115 or 230 operation on control phase.
*Denominator refers to control phase excitation.

Synchro Transmitters for use in position indicating (torque) systems and data transmission (control) systems. 60 and 400 cycle models, and sizes from 10 to 37 are available. Electrical accuracies of 7 min. in standard units.

SYNCHRO TRANSMITTERS

TYPE NO.	GOVT. DESIG-NATION	FRAME SIZE	FREQUENCY	FUNCTION	VOLTAGE RATING (VAC)	ELECTRICAL ACCURACY MAX. ERROR
K101570		10	400	Control Differential Transm.	11.8/10.5	30' SPD.
K101550		10	400	Control Transm.	26/11.8	24' SPD.
101B2A	11CX4a	11	400	Control Transm.	115/90	±7'
101B2A1	11CX4a-26V	11	400	Control Transm.	26/11.8	±7'
101B2J		11	400	Control Transm.	26/11.8	20' SPD.
105B2A	15CX4a	15	400	Control Transm.	115/90	±12'
105H2A	15CDX4a	15	400	Control Differential Transm.	90/90	±10'
105G2A	15TDX4a	15	400	Torque Differential Transm.	90/90	±10'
K101480		15	400	Torque Differential Transm.	11.8/11.8	20' SPD.
K101420		15	400	Torque Transm.	26/11.8	20' SPD.
K101400		15	400	Torque Transm.	26/11.8	20' SPD.
K101350		15	400	Control Differential Transm.	11.8/11.8	20' SPD.
106M2A	16CXB4A	16	400	Control Transm.	115/90	±12'
108B1B	18CX6A	18	60	Control Transm.	115/90	±8'
108B2A	18CX4A	18	400	Control Transm.	115/90	±8'
108H1A	18CDX6	18	60	Control Differential Transm.	90/90	±10'
108G2A	18TDX4a	18	400	Torque Differential Transm.	90/90	±10'
108H2B	18CDX4a	18	400	Control Differential Transm.	90/90	±8'
109M2A	19CXB4a	19	400	Control Transm.	115/90	±8'
112A1B	1 HG	** 1	60	Torque Transm.	115/90	±18'
113H2B	23CDX4a	23	400	Control Differential Transm.	90/90	±8'
113G2A	23TDX4a	23	400	Torque Differential Transm.	90/90	±8'
113F2B	23TX4a	23	400	Torque Transm.	115/90	±8'
113B2B	23CX4a	23	400	Control Transm.	115/90	±8'
113F1A	23TX6a	23	60	Torque Transm.	115/90	±8'
113B1A	23CX6a	23	60	Control Transm.	115/90	±8'
113G1B	23TDX6a	23	60	Torque Differential Transm.	90/90	±8'
113H1A	23CDX6a	23	60	Control Differential Transm.	90/90	±8'
121F1A	31TX6	31	60	Torque Transm.	115/90	±8'
121G1A	31TDX6	31	60	Torque Differential Transm.	90/90	±8'
121F2B	31TX4a	31	400	Torque Differential Transm.	115/90	±8'
121G2B	31TDX4	31	400	Torque Differential Transm.	90/90	±8'
121F2C	31TX4C	31	400	Torque Transm.	115/90	±8'

**Diameter same as size 23 units

Frame size indicates approximate diameter in tenths of inches

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Synchro R
den-Ketay
in position
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able in 60
sizes from

SYNCHRO

TYPE NO.	GOVT. DESIG-NATION	FRAME SIZE	FREQUENCY
K101540		10	400
105C2A	15TR4a	15	400
K101430		15	400
106K2A	16TRB4	16	400
108C1C	18TR6a	18	60
108C2B	18TR4a	18	400
109K2A	19TRB4a	19	400
112A1C	1F	**1	60
113C2A	23TR4a	23	400
113C1B	23TR6a	23	60
121C1A	31TR6	31	60
121J1A	31TDR6	31	60
121J1C	31TDR6S1	31	60
121C2B	31TR4a	31	400
121J2B	31TDR4	31	400
121C2C	31TR4C	31	400

(1) Pigtail Uni

*(1) 31TDR6S1–Pigta

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INDUCTION

TYPE NO.	GOVT. DESIG-NATION	FRAME SIZE	FREQUENCY	DUT
D11940		18	60	Contin
E11590	1G-60	10	60	Intermi
E11600	1F-60	**1	60	Intermi

Norden-Ketay offers
cycle excitation. Unit
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phase, 5 millivolts qu

Norden-Ketay also of
with or without integr
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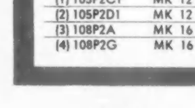
Special requirements

MOTOR DRIVEN, TACH

*For motor characteristics applicable to these

KETAY TYPE NO.	GOVT. DESIG-NATION	POWER INPUT (WATTS)	OUTPUT VOLTS @ 1000 R.P.M.
(1) 105P2C		5.4	3.2 R.M.S.
(2) 105P2D		5.4	3.2 R.M.S.
(1) 105P2C1	MK 12 MOD 0	5.4	3.2 R.M.S.
(2) 105P2D1	MK 12 MOD 1	5.4	3.2 R.M.S.
(3) 108P2A	MK 16 MOD 0	5.4	3.2 R.M.S.
(4) 108P2G	MK 16 MOD 2	5.4	3.2 R.M.S.



Norden-Ketay panca
0.5 in. or less, are av
is essential, as in gy
formers, and resolver

PANCAKE

KETAY TYPE NO.	FUNCTION	INPU VOLTA
B-14335 CX4	Synchro Control Transmitter	26 V, 40
B-14336 CT4	Synchro Control Transformer	26 V, 40
B-14335-1 CX4	Synchro Control Transmitter	115 V, 40
D-13718	Synchro, Resolver	40 V, 90

nits in mass production by Norden-Ketay

hro Receivers are used with Nor-
Ketay synchro torque transmitters
sition indicating systems. Accura-
of one degree or better are avail-
in 60 and 400 cycle units, and in
from 10 to 37.

HRO RECEIVERS

ENCY	FUNCTION	VOLTAGE RATING (VAC)	RECEIVER ERROR (MAXIMUM)
	Torque Receiver	26/11.8	±1¼°
	Torque Receiver	115/90	±1.0°
	Torque Receiver	26/11.8	±1.0°
	Torque Receiver	115/90	±1.0°
	Torque Receiver	115/90	±1.0°
	Torque Receiver	115/90	±1.0°
	Torque Receiver	115/90	±1.0°
	Torque Receiver	115/90	±1.5°
	Torque Receiver	115/90	±1.0°
	Torque Receiver	115/90	±1.0°
	Torque Receiver	115/90	±1.0°
	Torque Differential Receiver	90/90	±1.0°
	Torque Differential Receiver	90/90	(1)
	Torque Receiver	115/90	±0.8°
	Torque Differential Receiver	90/90	±0.8°
	Torque Receiver	115/90	±0.8°

Pigtail Unit Sensitivity 10'

–Pigtail Unit, Sensitivity 10'

Used with Norden-Ketay synchro control transmitters in closed cycle servo systems, Norden-Ketay synchro control transformers develop a voltage gradient of one volt per degree of system error. They are available with null voltages as low as 60 millivolts total and 30 millivolts fundamental and with accuracies as great as 6 min. in standard models which match Norden-Ketay synchro control transmitters.

SYNCHRO CONTROL TRANSFORMERS

TYPE NO.	GOVT. DESIG-NATION	FRAME SIZE	FREQUENCY	VOLTAGE RATING	ELECTRICAL ACCURACY MAX. ERROR
K101560		10	400	26/11.8	30' SPD.
K101530		10	400	12/11.8	24' SPD.
101A2K		11	400	11.8/0.4 V. per deg.	20' SPD.
101A2S	11CT4a	11	400	90/1 V. per deg.	±7'
105A2A	15CT4a	15	400	90/1 V. per deg.	±10'
K101300		15	400	26/11.8	20' SPD.
K101750		15	400	11.8/22	15' SPD.
K101300-20		15	400	10.2/26	17' SPD.
106L2A	16CTB4a	16	400	90/1 V. per deg.	±10'
(1) K402100		17	400	13.4/10 V. per deg.	
108A1A	18CT6a	18	60	90/1 V. per deg.	±8'
108A2B	18CT4a	18	400	90/1 V. per deg.	±8'
109L2A	19CTB4a	19	400	90/1 V. per deg.	±8'
109L1B	19CTB6a	19	60	90/1 V. per deg.	±8'
112A1A	1 HCT	**1	60	90/1 V. per deg.	±18'
113A2B	23CT4a	23	400	90/1 V. per deg.	±6'
113A1A	23CT6a	23	60	90/1 V. per deg.	±6'

(1) Linear Synchro

(1) High Impedance unit
(2) Linear synchro
(3) When used as control transmitter 26/11.8 VAC

orden-Ketay Induction Motors
re available in sizes 18, 20, and 23
rames. Three phase, 2 pole; 2
hase, 4 pole; and 3 phase, 2 pole
odels for 60 cycle operations are
vailable.

Norden-Ketay Resolvers ... from Coarse ±0.2% to Precision ±0.05% ... for use in computers, radar sweep circuits, phase shifters, and accurate data transmission systems.

CTION MOTORS

DUTY	OPERATING VOLTAGE	MINIMUM NO LOAD SPEED (RPM)	MINIMUM STALL TORQUE (OZ. IN.)
Continuous	3 Phase 115 V.	3300	3
Intermittent	2 Phase 115/40	1500	2.7
Intermittent	3 Phase 115 V.	3400	16

ffers precise tachometer generators for 60 and 400
. Units with linecrity of 0.1% are available in pro-
ies. Zero speed voltages are held to 5 millivolts in
lts quadrature, and 15 millivolts third harmonic.

lso offers servo motor driven tachometer generators
integrally mounted gear trains. Built for extreme am-
nts, these units assure dependability and long life.
nents and adaptations can generally be supplied.

TACHOMETER-GENERATORS

to these units, see corresponding motors as indicated.

TPUT OLTS 0 R.P.M.	NULL VOLTS @ 0 R.P.M. FUND. MAX.	LINEARITY (WITH RESPECT TO VOLTAGES @ 1000 R.P.M.)	MAXIMUM SPEED FOR LINEAR OUTPUT	ROTOR MOMENT OF INERTIA
R.M.S.	.025	±1%	4500	5.26 GM.CM.^{2}
R.M.S.	.025	±1%	4500	5.26 GM.CM.^{2}
R.M.S.	.008	±1%	4500	5.26 GM.CM.^{2}
R.M.S.	.008	±1%	4500	5.26 GM.CM.^{2}
R.M.S.	.008	±1%	4500	5.73 GM.CM.^{2}
R.M.S.	.008	±1%	4500	5.73 GM.CM.^{2}

*(1) K101600-6 (2) K101660 (3) K402560-1 (4) K402550-1

SYNCHRO RESOLVERS

TYPE NO.	GOVT. DESIG-NATION	FRAME SIZE	FREQUENCY	TOTAL NULL VOLTAGE MAX. AT TEST VOLTAGE	TEST VOLTAGE	INPUT IMPEDANCE OHMS	VOLTAGE RATING (VAC)	ANGULAR DISTANCE BETWEEN NULL VOLTAGE	MAXIMUM ANGULAR ACCURACY
(1) K101590		10	400	200 MV	26/12	2380/67.7°	26/11.8	90°±5'	30' SPD.
K101580-5		10	400	50 MV	26	560/62°	26/11.8		30' SPD.
101D2A		11	400	60 MV	26	1510/71°	26/22	90°±15'	±10'
101D2C		11	400	60 MV	26	440/76°	26/11.8	90°±15'	±10'
105D2C	15RS4L	15	400	25 MV	26	585/81°	26/11.8	90°±10'	20' SPD.
K101450		15	400	50 MV	26	2000/72.5°	26/18	90°±10'	40' SPD.
K101340		15	400	50 MV	26/12	465/61.3°	26/11.6	90°±5'	20' SPD.
(2) 105D2A2		15	400	10 MV	10	3280/82.1°	90/90	90°±5'	±0.1%
(2) 105D2K1	MK 4 MOD O	15	400	15 MV	15	890/78°	26/26	90°±5'	±0.1%
(2) 105D2K2		15	400	15 MV	15	890/78°	26/26	90°±5'	±0.15%
(2) 105D2K3		15	400	23 MV	15	890/78°	26/26	90°±5'	±0.20%
(2) 105D8D		15	1000 (Test)	30 MV	24	(4) 24.6 mh.	0-30	90°±5'	±0.2%
105D2Z		15	400	40 MV	26	950/82°	26/26	90°±20'	±20'
105D9E		15	500	75 MV	50	15,000 (Tuned)	50/50	90°±5'	±0.15%
113D1F	23RS6A	23	60	30 MV	24	570/79°	45/45	90°±5'	±.2%
113D2G	23RS4A	23	400	60 MV	60	234/83°	90/90	90°±5'	±.2%
113D1D	23RS6	23	60	60 MV	60	585/61°	90/90	90°±5'	±.2%
113D2E	23RS4	23	400	60 MV	60	720/80°	90/90	90°±5'	±.2%
113D3T1		23	400	16 MV	8	975/86° @ 10V	8/16	90°±5'	±8'
113D3T2		23	400	20 MV	8	975/86° @ 10V	8/16	90°±7'	±15'
113D3S1		23	350	30 MV	30	3200/86°	30/30	90°±5'	±8'
113D3S2		23	350	30 MV	30	3200/86°	30/30	90°±5'	±8'
113D3S3		23	350	50 MV	30	3200/86°	30/30	90°±7'	±15'
(3) 113D2P1		23	500	50 MV	50	7000	50/50	90°±5'	±5'
(3) 113D2P2		23	500	50 MV	50	7000	50/50	90°±5'	±10'
(2) 113D2R1	23RS4D	23	400	30 MV	60	3000/86°	90/90	90°±2.5'	±0.05%
(2) 113D2R2		23	400	60 MV	60	3000/86°	90/90	90°±5'	±0.10%
113D1B	23RS6S	23	60	30 MV	24	480/78°	24/24	90°±5'	±.2%
113D3J		23	350	30 MV	30	3200/85.7°	30/30	90°±5'	±0.15%
(2) 113D1N		23	60	26 MV	26	1140/76.3°	26/26	90°±5'	±0.1%
(2) 113D8H		23	1,000 (Test)	30 MV	24	(4) 16.25 mh.	0-30 V	90°±5'	±.2%
113D1Q1	23RS6B	23	60	13 MV	26	1020/81.6°	26/26	90°±2.5'	±.1%
113D1Q2		23	60	26 MV	26	1020/81.6°	26/26	90°±5'	±.15%
113D2A	23RS4B	23	400	20 MV	26	550/86°	26/26	90°±5'	±.10%
113D2C	23RS4C	23	400	30 MV	60	3200/86°	90/90	90°±5'	±.10%
105D2F	D-13310	15	400	30 MV	26	740/80°	26/26	90°±5'	±.10%

(1) High impedance unit
(2) Feedback Resolver
(3) Geared housing

(4) For these Sweep Resolvers input impedance is not considered. Instead, inductance at 1000 c.p.s. is important.

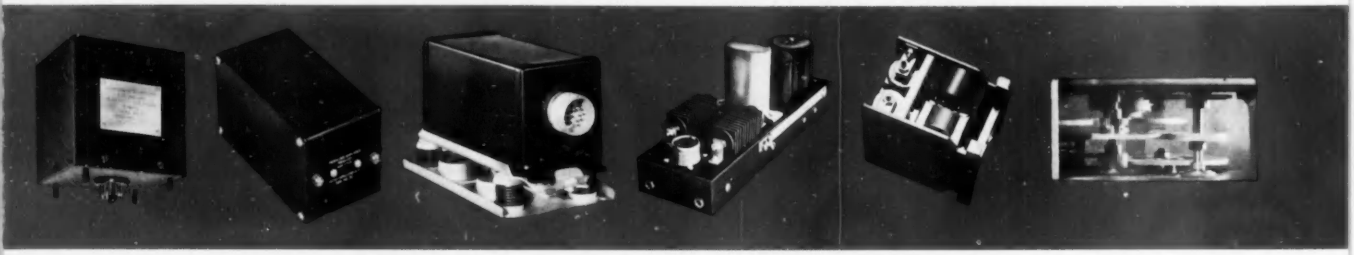
Inductance at 1000 c.p.s.	113D8H	105D8D
Rotor winding	17.7 Mh	27 Mh
Main Stator winding	16.2 Mh	24.6 Mh
Feedback Stator winding	16.2 Mh	24.6 Mh

pancake synchros, with maximum thickness as little as
re available for applications where minimum thickness
in gyro pickoffs. Control transmitters, control trans-
solver models are available.

CAKE SYNCHRO

INPUT VOLTAGE	INPUT CURRENT	INPUT POWER	OUTPUT VOLTAGE	ANGULAR ACCURACY
26 V, 400 CPS	155 Ma.	2.1 W.	11.8 V.	±20'
26 V, 400 CPS	80 Ma.	1.0 W.	11.8 V.	±20' 0.4 V./Deg.
15 V, 400 CPS	80 Ma.	5.1 W.	90 V.	±20'
40 V, 900 CPS	6 Ma.		40 V.	±.20%

AMPLIFIERS AND GEAR TRAINS



Amplifiers can be made in open, dust-proof or hermetically sealed packages. They can be individually designed and modified to meet customer's electrical, mechanical and environmental specifications. Gears and gear trains of conventional and miniaturized types are available to meet the most demanding of design requirements.

MAGNETIC AMPLIFIERS

Magnetic Amplifiers are designed for use in Servo Systems employing two phase low inertia induction motors. They require no external tubes or separate bias, and operate directly from a line supply. They employ the latest half-wave self-saturating circuitry, insuring low response time, high gain and compactness. The half wave reset mode of operation of these units supplies very desirable quadrature rejection. These Magnetic Amplifiers are noted for long life, ruggedness, and dependability.

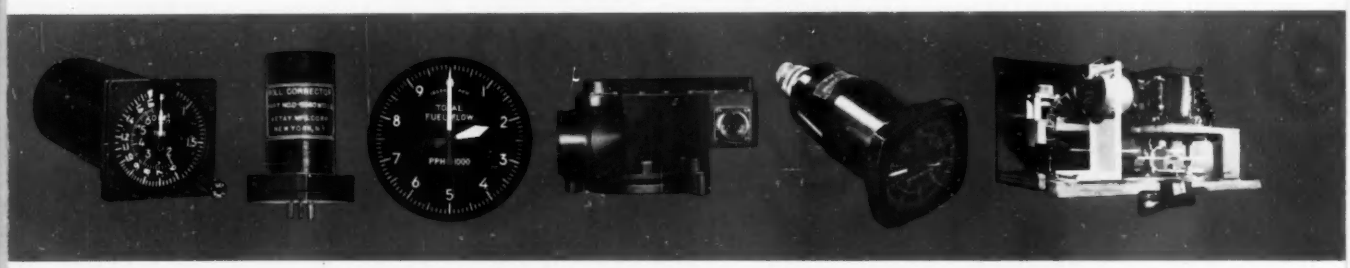
RESOLVER AMPLIFIERS

Resolver Amplifier Systems are made for precision resolver applications where accuracy, isolation, and reliable operation under severe environmental conditions is paramount. Subminiature packaging techniques, preferred type tubes and quality components assure reliability, compactness and long life. Two basic system types are standard: a system connection employing summing resistors; the other, where the input signals are series summed with the compensating winding signal and fed to the grid of the high gain amplifier.

SERVO AMPLIFIERS

Dual Channel Servo-Amplifier, Type SEA 4-310, is made for servo-systems using miniature two-phase servo motors. Each amplifier channel is capable of accepting input error information, either in-phase or 90 degrees out of phase with the line of reference. Separate input terminals are provided for these inputs. For in-phase signals, the amplifier circuits provide the required 90 degrees phase shift for operation of the servo motor. Hence, the motor fixed field can operate without external phasing capacitors. Tuning capacitors for motor control fields are provided as integral part of each amplifier for power factor correction.

CONTROL DEVICES



Many control devices, designed and developed by Norden-Ketay engineers, are being produced in mass quantities. Custom engineered units, featuring resistance to humidity, corrosion and high temperatures, or having special configuration and other non-standard characteristics, will be made to meet the needs of your particular application.

Norden-Ketay designs and manufactures a large variety of airborne instruments for engine and flight operation, for many aircraft, missile, marine, ordnance and civilian applications. Included are many special designs insuring a high level of performance, while meeting limitations of space and operating conditions. Norden-Ketay research laboratories are staffed and equipped to co-operate with engineers that find a need for electronic control devices in their particular project.

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INDUSTRY'S PULSE

Controls Pace Southeast Industrialization

In fifteen years Florida's manufacturing output has risen 500 per cent. Meanwhile, Georgians too have flocked from farm to factory. In 1940, 43.6 per cent of them grew peaches, pecans, cotton, etc. Today 27.9 per cent cultivate the rich red soil.

These figures typify the pace of industrialization throughout the Southeast. New and expanded factories have made the region a top market for instrument and control makers. And competition among the myriad small plants is so keen that even some relatively new ones remain steady customers. For example, the Macon Kraft Co., Georgia papermaker, now uses 50 per cent more instrumentation than it did just seven years ago when the plant was built.

Controls crown King Cotton

From boll to bolt, cotton, still kingly, wears a crown of measurement and control. So do the other textiles that make up the Southeast's largest industry. Most of the instrumentation was developed in mills to solve pressing problems. And some mills make equipment for their own use or even for sale. But thousands of small operators rely entirely on controls that come packaged with modern textile machines.

Profit margins are so perilously slim in textiles that mills must insist on the most finicky measurements. Precise instruments are now available to gage such fiber characteristics as average length, distribution of length, average diameter, strength, friction or drag, color, and maturity. Up to the yarn stage, automatic control lags behind measurement techniques. But in weaving, mills carefully control tension and moisture. And in the finishing stages, particularly dyeing, controls take over in elaborate fashion.

Computer centers aid business, education, research

The Southeast boasts at least 30 major computer centers, an outstanding example being Georgia Tech's new $370,000 installation. In this center the machines, including a big ERA 1101, are used for teaching, for solving problems arising from student and faculty research, and for providing consulting and computing service to business and industry. Nearby, the Georgia Power Co. depends on the world's first incremental cost computer to maximize the efficiency of power generation and distribution.

Instrument and control makers are relatively new to the Southeast. In Melbourne and Orlando, Fla., Radiation, Inc., is

developing and producing a broad line of electronic and electromechanical equipment. Fairchild Aircraft has established its new Speed Control Div. in St. Augustine.

Sperry Gyroscope turns out guided missile components in Bristol, Tenn. The University of Tennessee physics department has been particularly active in developing textile fiber instruments. Special Instruments Laboratory, Inc., in Knoxville makes several of the UT instruments.

Industries pay plenty for controls

Southeastern industry is becoming increasingly control conscious. One power plant spent \$2.5 million to reduce operators from 26 to 6 men per shift. A modern hospital being built in Atlanta has a boiler plant whose controls and instruments represented 50 per cent of the boiler room cost. About the region as a whole, these generalizations seem valid:

- More companies are hiring instrument engineers in addition to instrument mechanics.
- Scanning techniques are becoming popular for assembling and collating the information on instrument panels.
- Process industries are building more central control rooms, although some engineers feel that these rooms tend to become too large and complex.
- Electronic control seems interesting, but most plants are sticking to familiar, reliable pneumatic systems.

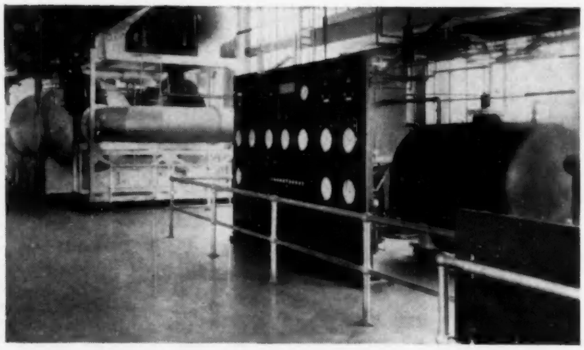
The Southeast still relies on other regions for the bulk of its instruments and control equipment. But in at least one place the dependence is being reversed. Researchers at Oak Ridge National Laboratory are solving control problems that conventional industries have not yet even encountered. Instruments for "hot" areas must be super-reliable because they are so hard to maintain. And work is being done on flow control in the neighborhood of 1 cc per min. Thus while drawing on the instrument and control industry as a whole, the Southeast is depositing its share of technological ingenuity.

WHAT'S NEWS AT BRISTOL . . . WHAT'S NEWS AT BRISTOL

Bristol...automation... and you

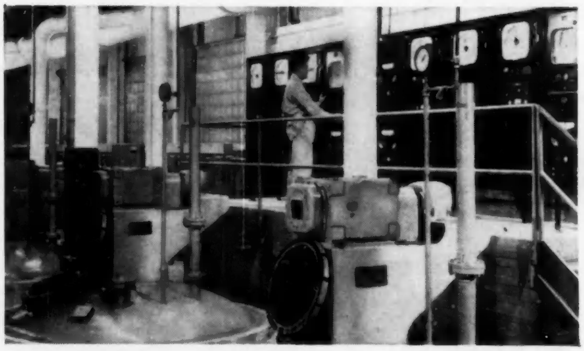
Magic word, automation. Or push-button operation. It's a breath-taking concept, too — plants running practically unattended.

Breath-taking — but not *new*.

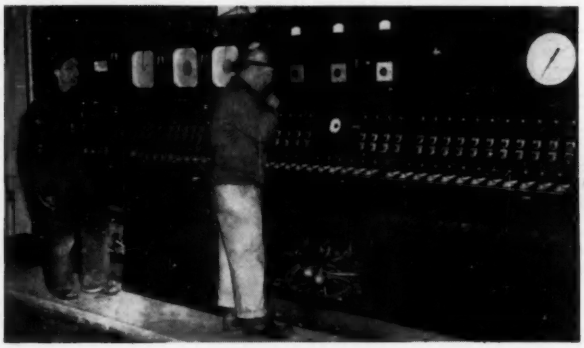


BRISTOL COORDINATED CONTROL SYSTEM automatically controls operation of "Columbia" Activated Carbon Solvent Recovery Plant at the New York Daily News. Similar control systems are used in many other solvent recovery plants designed and supplied by Carbide and Carbon Chemicals Company, a Division of Union Carbide and Carbon Corporation.

BRISTOL'S "MECHANICAL BRAIN" is the leader of the Coordinated Process Control System . . . accurately coordinating all the variables, including mechanical operations, so that each phase of the process takes place in proper sequence.



AUTOMATION is often thought of in terms of plans or even dreams; here at the Buffalo Foam Rubber Products Plant of the Dunlop Tire and Rubber Corporation, it is a reality. This automatic plant, designed and built by Mechanical Handling Systems, Inc., Detroit, uses Bristol Dynamaster® Electronic Instruments and Automatic Controllers as part of a process employing today's most advanced automatic production techniques. The result — greater efficiency and productivity, lower costs, improved product, and stronger competitive position.



THE WORLD'S LARGEST COAL CLEANING PLANT employs automation in lubricating system. The Hanna Coal Co., Adena, Ohio, uses *Bristol Controls and Recorders* in its fully automatic time-controlled centralized system for mass lubrication. This system promotes safety and, above all, insures positive delivery of the right lubricant in the right quantities at the right time to all bearings, regardless of operating conditions.

Control ENGINEERING
APRIL 1955

Broaden Your Scope

Modern control systems are often strange mixtures of principles and technologies. Their very oddness carries an important implication for control engineers.

Control systems almost always have some moving parts; that is, they are partly mechanical. The remainder may be electric or pneumatic. Or it may have optic or hydraulic elements, or even nuclear radiation sources.

The measurements may involve the characteristics of thermal, chemical, or electromagnetic systems. And the properties of the more and more varied controlled system also must impress themselves on the controller.

The probability, then, is not that these systems might be odd-seeming mixtures but that they must be such. The fact that they are already an incredible variety of disparate devices called upon to work in harmony is well known to the control engineer. That they will become still more so is evident. Every day automatic control is being demanded by different and previously uninterested industries.

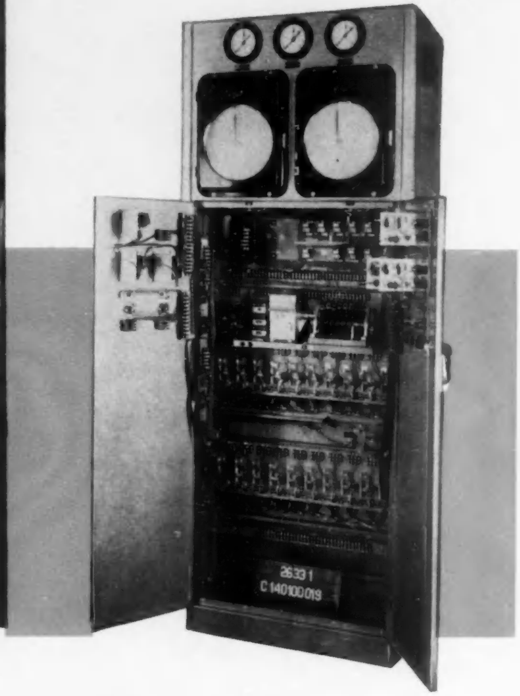
Any single control system may contain many techniques that until now have been properly part of different engineering specialties. To make it worse, the most efficient solution to a particular problem may involve using a method different from the "obvious" solution, a method with its roots in one of these specialties.

From the systems viewpoint, the control engineer must be able to describe the dynamics of every part of the control loop, regardless of the specialties involved. This would seem to require that the control engineer be more than an engineer. He must be a scientist, if the breadth of his knowledge is the qualification.

Since most of our engineers are the products of specialized undergraduate curricula, there is a great need for an awareness of this peculiarity of control to become all things at once. The scope of the field indicates that the control engineer must broaden his knowledge if he would do his job properly.

Control Engineering helps by supplying the ties with which these seemingly loose ends can be bound into one coherent field. But the primary educational job really falls where it always did: at the undergraduate level in our colleges and universities. The colleges must start turning out young men who can apply themselves in all of the many arts embraced by automatic control. Men who specialize in nothing: Nothing but control, that is.

THE EDITORS



Typical bank of centrifugal pumps in a tankless water distribution system. Motors are shown, pumps are below the floor. FIG. 1

Control cabinet for tankless water system at Dow Chemical Co. Pumps in Figure 1 are controlled from a cabinet like this. FIG. 2

Keep Water Pressure Constant Through Pump Control

BRUCE A. JAMES, Automatic Control Co.

The goal of any water system is constant pressure—constant pressure no matter what the demand.

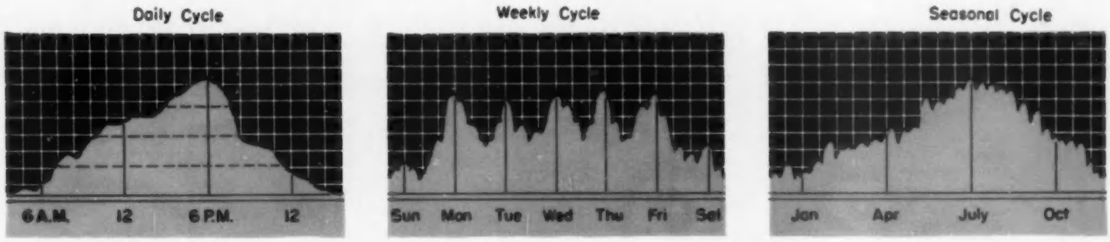
The average user, though, is not much concerned about constant pressure. Rather, he wants pressure constantly. Pressure variations don't bother him so long as every time he opens a tap, water gushes forth.

But there is a world of difference between having pressure constantly and having constant pressure.

There are only two ways we can ensure a constant flow of water. One is to make the demand constant. But practically speaking, demand is never constant. And whenever an industrial system draws from a municipal system there is an even greater demand variation. Demand is the most variable factor of all—unless we set up a separate system for each tap.

The other way to assure constant water flow is to keep pressure constant. As demand changes throughout the system, so does pressure, unless we compensate automatically for demand changes. And if we overcome demand changes, we can keep pressure constant, regardless of drawoffs.

How can we do this? Let's look at the three ways to get water from the earth to the user.



THE GIST: Supplying water for industrial and municipal systems is a complex and costly proposition. A water distribution system for a large industrial plant may have supply requirements ranging from 1,000 to 10,000 gallons per minute for such a variety of things as an overall fire protection system, a treatment plant for boiler feedwater, an air conditioning system for cooling, and process vats for manufacturing—all in addition to a standard sanitary system. These facilities need an approximately constant-pressure water supply, even in the face of daily, weekly, and seasonal demand fluctuations such as shown on the accompaning charts. There are several ways to supply water for such a system. But only the tankless method, using multiple pumps, automatic control, and programming, will perform well at low cost while keeping the supply pressure within close limits.

First is the reservoir. The initial cost is high for an elevated tank, and the pressure is not as stable as often assumed.

Second is the hydropneumatic tank—the pressure tank. It is wasteful of both power and pump when demand is high. The pumps have to run nearly continuously, and any time pump cycles (pump on, pump off is one cycle) go above six an hour, motor-starter and pump wear is exorbitant.

The third way to get water to the user is a tankless system—using pumps alone to supply the demand. Such a system has many benefits. Initial costs are low. And pump wear is held to a minimum, for pumps run only when needed. Best of all, a tankless system closely approaches our ideal of constant pressure in spite of demand changes.

In a tankless system, water is pumped directly to the user. It flows from the pumping station under nearly constant pressure, regardless of demand. So we get constant pressure and high operating efficiencies but have no large investment.

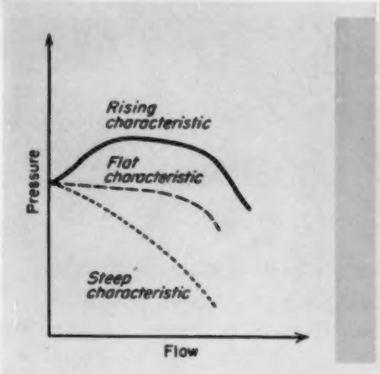
Pump and control specifications for the tankless system can be accurately graphed in the design stages. System design starts with figuring demand variations—from maximum to minimum. Then the constant pressure we want is determined. When we have figured the head and flow needed, we look at pump characteristics (Figure 3, next page).

Elevated tank systems use pumps with a "steep curve." Such pumps have a relatively small change in flow rate for a substantial head variation (Figure 4) and so are ideal for supplying a fairly constant flow to the tank, to keep friction loss constant.

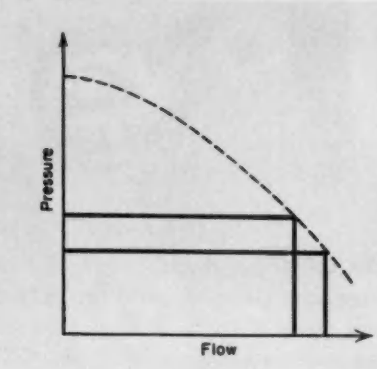
Pumps for the tankless system are selected on an entirely different basis from pumps for the elevated tank. The "steep-curve" pump is entirely unsuited for the tankless system. Here we need pumps with the opposite characteristic—a wide variation in flow with a small pressure difference. Pumps in a tankless system are used as a flow meter and no orifice plate or venturi tube sensing element is needed to operate the controls (Ed. note—an interesting concept; using the system actuator or power element to monitor the controlled variable instead of a separate sensing element).

Because pressure drops with increasing flow and rises with a diminishing flow, limits of pressure variation are determined by the pump and not by the control (Figure 5). The flatter the pump curve, the smaller the pressure variation.

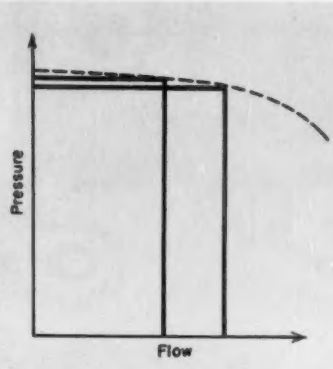
From the standpoint of surge and fluctuation, this tankless system is the most stable of the three systems. In an elevated-tank system when the pumps aren't running and the tank alone supplies demand, pressure charts resemble Figure 6A. With the pumps operating, the running surge is reduced as shown in Figure 6B, since the pump partially compensates for demand variations that cause surges.



Characteristics of centrifugal pumps: constant speed and suction head. FIG. 3



Steep characteristic curve as in elevated tank systems. FIG. 4



Flat characteristic curve for pumps used in tankless systems. FIG. 5

The "flat-curve" pump used in the tankless system can absorb even more fluctuations. Under similar conditions the pressure chart is much smoother (Figure 6C).

Demand, as we said before, is not constant. Since it is costly in machinery and power to use more horsepower than needed, a tankless system always has more than one pump. Thus, when demand is at a minimum, one small pump is adequate. As demand goes up, more pumps are cut in, keeping the pressure as constant as possible. Instead of designing a system only for maximum capacity, it also can be designed for trends in consumption.

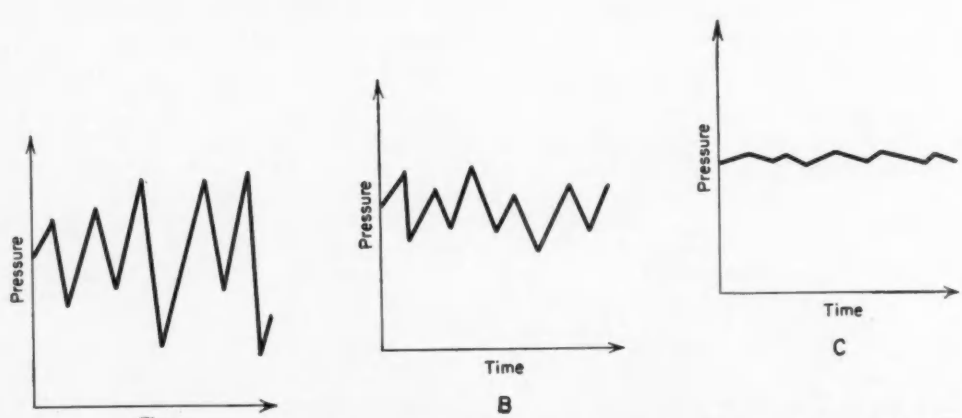
SEQUENCED OPERATION

We can have pumps all the same size or pumps of different sizes in a tankless system.

If we have multiple pumps of equal capacity and identical curves, we run them in sequence. As demand increases, more pumps turn on automatically. Figure 7 shows composite curves for a group of pumps. The system friction curve at the bottom of the diagram determines the location of the transfer point in sequence operation. The intersections of the horizontal lines marked **low limit** and **high limit** with the pump curves are the control points.

To maintain pressure in a sequenced system, one pump is run continuously. This, the lead pump, is selected for minimum demand only. As demand increases, the flow increases and the pressure drops to the intersection of the low-limit line and the first pump curve (Figure 8). This point is sensed by the control which automatically turns on a second pump to increase the system pressure. If demand increases further still, pressure decreases along the second pump curve, until the third pump is turned on.

Each time a low limit is reached, the control automatically transfers the system to the next curve by adding an additional pump. This continues until the demand stabilizes at some point. Under normal



Time

A

Pressure variations in elevated tank and tankless systems. (A) Elevated tank; pump not operating. (B) Same; pump operating. (C) Tankless system; pump operating. FIG. 6

conditions, the demand will stay in balance for a while and then either increase further or diminish.

When the trend reverses, the pressure ascends along the pump curve until the high-limit line is reached. At that point the system is transferred back to the preceding curve, cutting out the last pump. This process continues until the demand stabilizes. Each time the high limit is reached, the number of pumps running is reduced and demand is supplied with less horsepower.

When there is no demand the lead pump continues running. To prevent cavitation, a bypass is installed in the line so that water is constantly fed to the pump.

When the change in demand causes a shift to another curve, the intercept on the new curve is below the high-limit (or above the low-limit) line. This is essential to prevent hunting. An overlap (the shaded area in Figure 9) must be provided.

To approach the ideal of constant pressure (represented by the norm line in Figure 10), the high-limit and low-limit lines must be as close to the norm line as possible—a condition that depends on the shape of the pump curves. The flatter the curves, the narrower the field between the high and low limits. As we said before, the curve is determined by the pump rather than by the control system. For any tankless system it is not enough to specify a nominal pump rating; specific deliveries at high and low limits plus maximum efficiency between these limits are required.

Such a system will run smoothly without shock or surge. If pumps are properly selected and controlled, there is no need for manipulating valves or using hydraulically operated cone valves. And if one of the pumps in the sequence is disconnected, the control system will automatically cut in standby pumps.

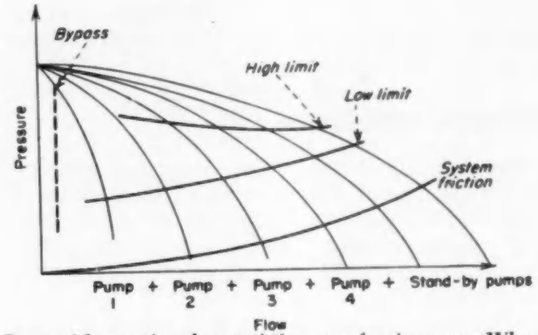
PROGRAMMED OPERATION

So much for tankless systems using equal-capacity pumps. Multiple pumps of unequal capacities are operated in a programmed arrangement. Here the load is shifted from one small pump to several small pumps, then to one large pump. This system is more complex than a sequence operation arrangement, since the load is shifted from a pump of small capacity to a larger pump, and back again.

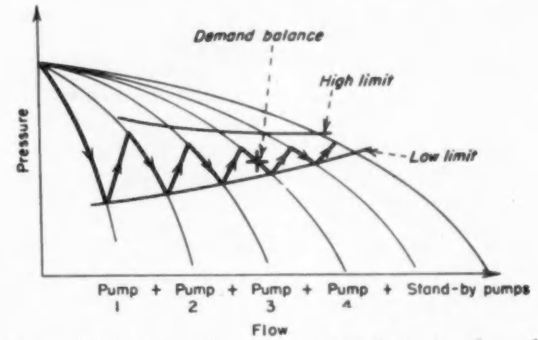
The lead pump is selected to meet minimum demand while others develop a smooth curve.

Figure 11 shows such a curve for four pumps, five steps. Two pumps are of one size and two of another—a practical selection that not only gives standby protection, but also helps equalize wear with alternate use.

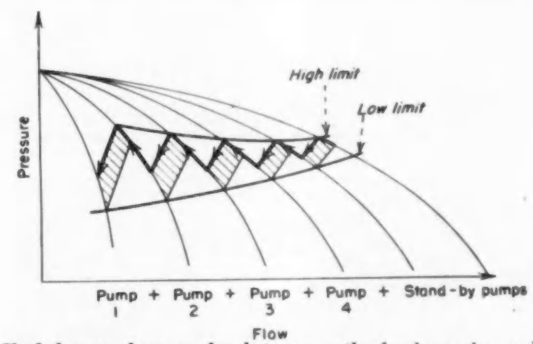
The operation of this system is similar to the sequence type, except that the control system must provide one additional feature. When a smaller pump is cut out in favor of a large one (or vice versa), the control system must keep the former



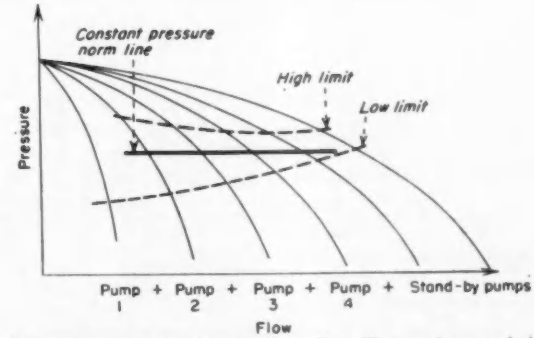
Sequential operation characteristic curves for six pumps. When each pump starts, the corresponding curve applies. FIG. 7



Sequential operation of pumps to meet increasing demand. Similar curve is followed for decreasing demand. FIG. 8



Shaded areas show overlap between paths for increasing and decreasing demand. Overlap prevents hunting. FIG. 9



Object is to operate close to norm line. Flatter characteristic curves means narrower limit zone. FIG. 10

pump in operation until the new one can pick up the load. With proper controls the pump transfer is smooth without surging.

SUCTION PRESSURE

Pump curves are based on zero suction pressure. But suction head (intake pressure) often varies in water-supply systems. A variation in suction head causes pump curves to shift, changing their output pressure in proportion to the change in suction pressure (Figure 13).

This situation can develop in deepwell pumping where drawdown of the water table occurs during heavy pumping periods.

Our discussion of pump curves was based on constant suction pressure. With changes in suction pressure, the norm and the high-pressure and low-pressure limits all shift. The high-pressure limit drops below the previously established low limit.

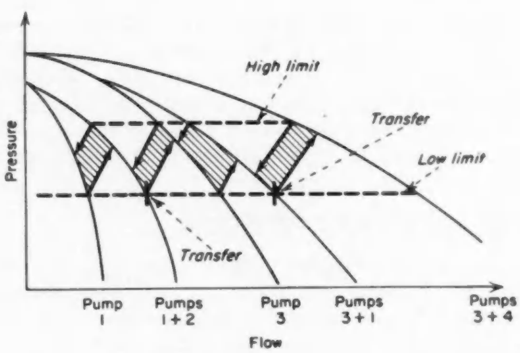
The object then is to return the pressure back to where it was before the change in suction pressure, or to go from point A to point B (Figure 14). But it is impossible to go from A to B.

The ideal way to handle variable suction pressure is to eliminate it. This can be done by a small sump at the intake side of the pump (Figure 15). This will hold suction pressure at a relatively constant value, regardless of variations in the sump supply. When system demands drop, the sump supply can bypass back to the source. For example, if it were a deepwell system discharging into the sump, under low-demand conditions the overflow could be discharged back into the ground. This is the best solution to varying suction pressures.

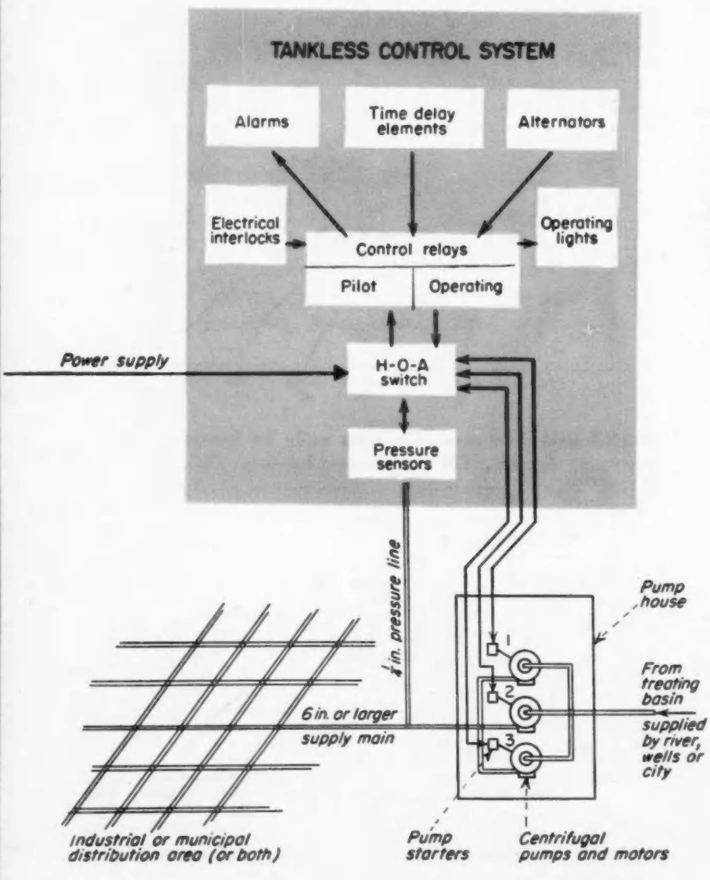
However, there are compromises. One of these is to zone the suction pressure. Between A and B (Figure 14) an infinite number of zones could be established. But from a practical viewpoint it's desirable to establish a minimum number of zones.

The high limit of one zone must be higher than the low limit of the following zone. Also as pumps are withdrawn or added, the return from one curve to another curve must be on a different line so that hunting doesn't occur. Zoning suction pressure requires a lot of analysis and paperwork.

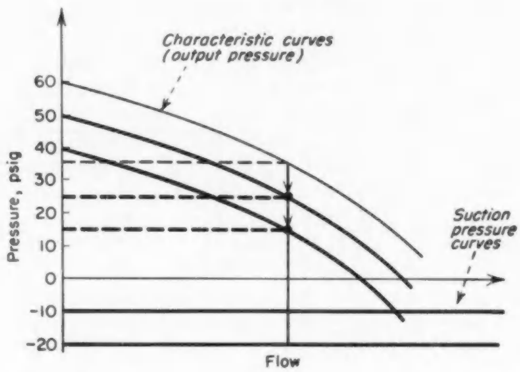
A better compromise solution is to continuously balance the suction pressure against the discharge



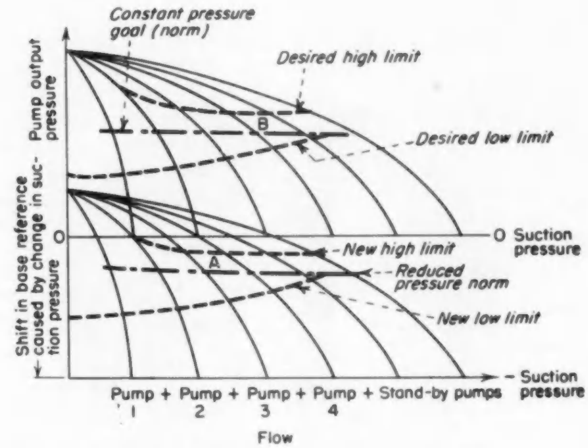
Programmed operation characteristic curves for four pumps. Two different sized pumps are used so that program can be alternated. FIG. 11



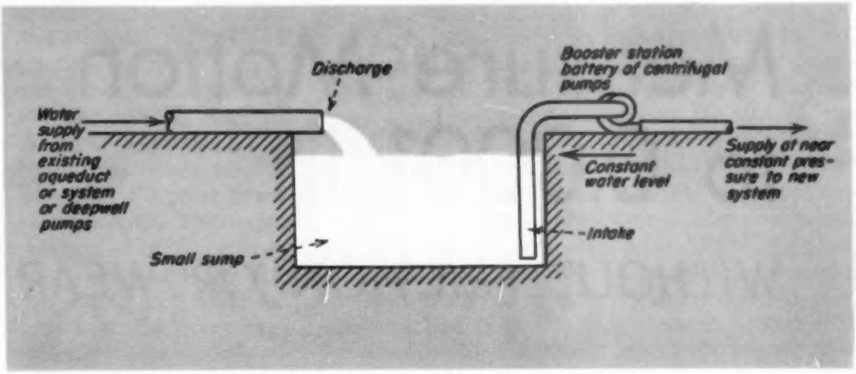
Typical system diagram for a tankless water distribution system. It consists of distribution area, pumping station and control equipment. FIG. 12



Suction shift from 0 to minus 20 psig causes output shift from 35 to 15 psig. FIG. 13



Change in output pressures caused by drop in suction pressure. This shift should be compensated. FIG. 14



One way to compensate for a shift in suction pressure is to eliminate it. This can be accomplished by a small sump at the intake to the pumps. FIG. 15

pressure. A balance amplifier senses the suction pressure. This is used to correct the base level of the pressure-sensing element.

Some feel variable suction pressure is not a problem, but rather flow is the determining factor. This is wrong when applied to the tankless system, since the pump curve is the controlling characteristic.

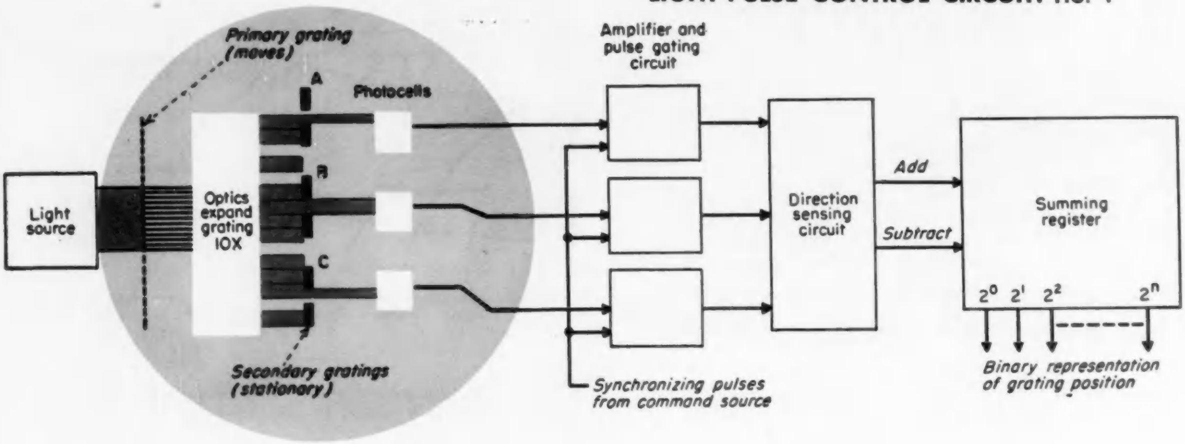
CONTROL SYSTEM OPERATION

An automatic control system for sequence or programmed operation of a multiple-pump tankless system includes sensitive pressure or float sensors, pilot and operating relays, alternators to equalize pump wear, and such protective devices as interlocks, time-delay elements, and alarms (Figure 12). Often remote transmission circuits also are necessary.

Sensors detect system pressures. These operate pilot relays when the predetermined pressure limits are reached. The pilot circuits operate load relays, which turn on or off pump motor-starters to maintain constant pressure. Electrical interlocks compensate for friction-loss changes that occur as different capacity pumps are introduced into the system. Time-delay elements prevent pump operation from surges. Other protective devices shut off the system when pump suction pressure drops below safe limits, preventing damage from dry operation. Automatic alternators shift pump sequences to equalize wear.

Controls mean everything to the tankless system, for far better than any operator they can turn pumps on and off to meet changing demand conditions, yet always keep pressure as nearly constant as possible. And controls must always be allowed to set the minimum load, for they will maintain adequate pressure and flow automatically.

LIGHT-PULSE CONTROL CIRCUIT. FIG. 1



Measure Motion to 0.0001 In.

WITHOUT FRICTION OR WEAR

Experiments with optical gratings and photocell pickups further demonstrate the practicality of using light pulses to measure machine tool travel even to an accuracy of millionths of an inch if necessary.

J. H. BROWN, Servomechanisms Laboratory, MIT

When the Servomechanisms Laboratory of MIT wanted to apply automatic control to a milling machine, the problem of accurately measuring motion over a distance of 6 ft had to be solved. Accuracy requirements of the digital electronic control system using punched paper tape input were arbitrarily set at .0005 in. Adequate measurement was accomplished with synchro receivers coupled to the milling machine through racks and gears.

Hopes of advancing accuracy to 0.0001 in. called for investigation of optical techniques. Indeed, the combination of optics and electronics promises to couple the high accuracy of optical mechanisms, the wearless action of photo-electric pickups, and the high speeds of electronic control circuits.

Commonly available for spectrometer use are optical gratings consisting of lines on highly polished glass spaced from 500 to 30,000 to the inch by photographic or metal deposit techniques. Using the motion of such a grating to interrupt a thin slit of light results in a series of light pulses. Counting these pulses with a photocell connected to an electronic counter makes it possible to read off the distance the grating has traveled.

Differentiation between backward and forward motions adds pulses for one direction and subtracts them for the other. The number shown in the register will then always correspond to the position of the grating. Placing another number in the counter—a command number—and using the pulses from the grating to reduce this number to zero, closes the loop, light pulses being the feedback signal.

The command number from the "director", it will be noted, is not a set-point value, but a change-of-

position value. Thirty "added" pulses from the director means that the machine must move 30 steps. As the machine moves the 30 steps, it diminishes the number 30 in the summing register, so that when the machine is at its new "target point," the summing register indicates zero. If the machine is to be moved in the other direction, 30 "subtract" pulses enter the summing register, making the grating introduce 30 "addition" pulses into the register.

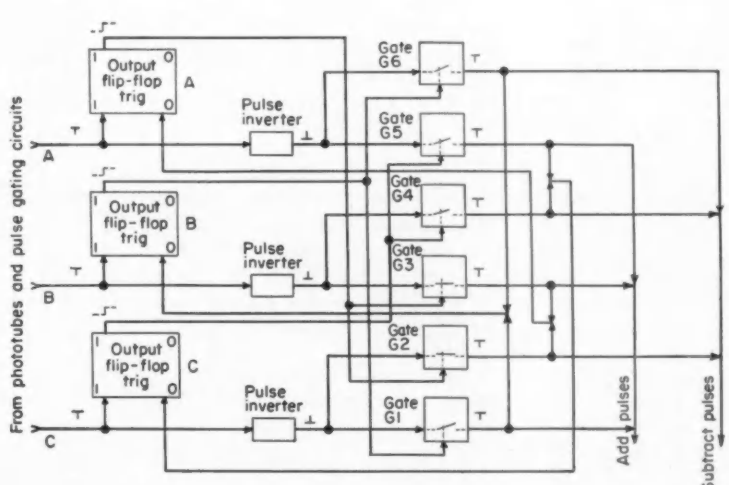
Information on the direction of motion can also be obtained directly from the light pulses. Let us say that three phototubes are so placed that only one at a time is fully exposed to light coming through two gratings, one motionless, the other traveling. As shown in Figure 1, three stationary "secondary" gratings are 120 degrees "out of phase" with each other. The stationary gratings have the same line spacing as the moving "primary" grating, although the diagram show them as single slits. Thus only one secondary grating at a time can have its lines coinciding with those of the primary grating. When the primary grating goes to the left, a full pulse of light goes through the secondary gratings to their associated phototubes in the sequence A, B, C. If immediately after passing a light pulse through C, the primary grating moves in the opposite direction, the light pulses would run in the order C, B, A. If the grating continues to move, the effect is C, B, A, C, B, A, etc. If a circuit can then detect whether the A pulse is preceeded by a C or a B pulse, it will indicate the direction of grating motion. This creates a vernier effect since the motion of only one space by the primary grating has been used to produce three full electrical pulses. Using four secondary gratings, as does the MIT machine, the direction-of-motion-circuit remains essentially the same, only one stage larger, but the accuracy of the system is larger by another factor. Hence, a primary grating with 2,500 lines to the inch can be used to provide 10,000 pulses per inch of travel, with four phototubes and four secondary gratings.

Figure 2 illustrates the operation of the direction-sensing circuit. In practice, one of the flip-flops is always in the 1 state, and the other two in the 0 state. Let us say that flip-flop A is in the 1 state. Gates G_3 and G_2 will be closed. A pulse coming from phototube B will go through G_3 to the "add" input of the summing register. If the pulse comes from phototube C, it will pass through gate G_2, and enter the "substract" input of the summing register. If the latter takes place, the pulse will also go to the 0 input of flip-flop A, driving it to the 0 state. This pulse will have also driven flip-flop C to the 1 state. Gates G_4 and G_5 will now be closed.

GRATINGS

Commercial gratings are available which have an integrated, or summed, accuracy of one part in 10,000. For an accuracy of 0.0001 in. with three viewing units primary grating could be no longer than 3 in. Four viewing units would increase the minimum primary grating length to 4 in. The addition of photocells and secondary gratings increases the size of interpreting circuits proportionally, however, placing a practical limit on primary grating length to well under 1 ft. To avert this difficulty, any number of lengths of staggered, or slightly overlapping, primary gratings can be used, each separately mounted and adjusted to compensate for accumulative inaccuracy.

As might be expected, the greatest difficulty in the construction of grating measurement systems is the mechanism for electrically sensing the passage of the



The direction-sensing circuit in detail. FIG. 2

waves of light produced by the moving gratings. As the beams of light produced through the gratings are too narrow to be used with a conventional light source and photocell pickup, optical manipulations are required. The RCA 1P42 phototube being about ¼ in. diam makes possible a fairly simple optical system, however. At the suggestion of Bausch and Lomb, who made the gratings used, the image of the primary grating was enlarged ten diameters and projected onto the secondary grating, which was made correspondingly larger. The slits were now of a size suitable for direct application onto the phototube, with suitable masking.

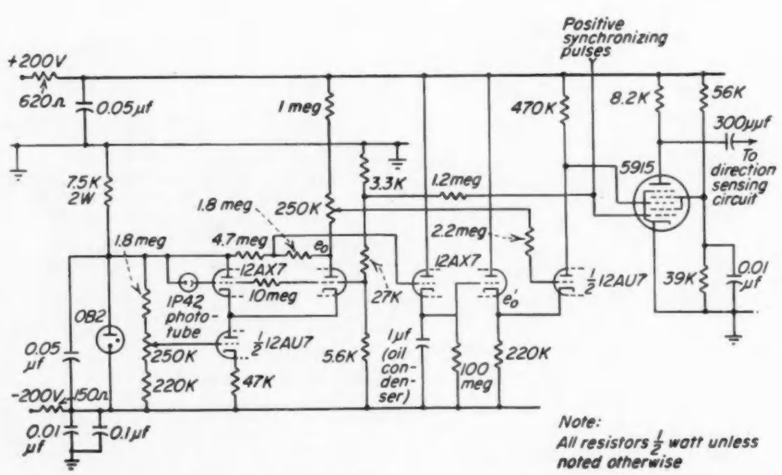
However, the problem of utilizing the output from the phototube is not so easily solved. The maximum output of the phototube is approximately 0.1 microamperes for the maximum light transmitted by the gratings. If the anode of the phototube is kept above 20 volts, and a 10 megohm load resistor used, the maximum voltage output of the tube is 1 volt. Because of stray light within the system and light defraction caused by the grating and the lens system, the minimum amount of light passing through the gratings produced a voltage of 0.4 maximum. To provide for changes in characteristics of the phototube, the gating circuit should operate when the output of the phototube changes to 0.8 volt. However, although the maximum table speed of the milling machine would produce a 128 cps output on each phototube, the minimum speed is very slow. This created problems in coupling a phototube amplifier to the gating circuit, which operates on a 10 volt change. Line variations, heater changes, plus phototube and light source aging being emphasized by direct coupling, a 1000 cps carrier was used to enable indirect coupling. Despite attempts to compensate for them, the high impedance and stray capacitance of the phototube made this approach impractical. The circuit finally chosen uses direct coupling throughout, and is shown in Figure 3. It will operate the gate on a phototube voltage change of 0.2 volts.

This circuit contains the amplifier for the phototube, a current-level selector circuit, and the pulse gate circuit. The current-level selector circuit is specifically designed to overcome the slow amplitude variations of the phototube, its amplifier, and the light source. Heart of the current-level circuit is a storage circuit which compares the value of previous maximum currents with incoming pulses, operating the gate circuit when a difference occurs. This circuit is designed to accommodate itself to slowly changing amplitudes—changes that occur at a rate less then the slowest likely motion of the machine measured. Different rulings of the gratings, especially those producing 100 per cent cutoff of the transmitted light, would considerably simplify the circuits. Involved in the design of such gratings would be grating diffraction and the resolution of lens systems used, including that of the light source.

Statements made about grating dimensions would be contingent upon these factors, which should be fairly amenable to experimental manipulation. Two gratings with equal slit width can be directly superimposed, for example, and the ratio of clear space to opaque spacing can be adjusted by moving the two gratings relative to each other.

The basic notions of this system, without gratings, can be adapted to interferometer setups as well, providing accuracy in the range of at least 0.00001 in. and possibly three or four millionths of an inch.

Through work such as this in the U. S. and abroad, the old technical and economic barriers that have restricted machine tool design are yielding. Designers should have fewer measurement and control restraints to cope with in the future.



The phototube amplifier circuit, current level detector, and pulse synchronizing circuit. FIG. 3

WHAT'S AVAILABLE FOR

High-Pressure Measurement and Control

High pressure operation is an art, rather than a science, practiced by ingenious engineers and technicians. This article describes the special equipment and techniques they have developed for measurement and control. It also suggests and discusses techniques not yet in service.

W. H. HOWE, The Foxboro Co.

MEASUREMENT OF HIGH-PRESSURE REACTIONS, essential in itself, provides the necessary information for control. Unstable high pressure reactions require automatic control to:

- ▶ Produce to specification
- ▶ Ensure the safety of plant and personnel.

Around the basic framework of measurement and control are the bounds imposed by:

- ▶ Physical limitations of the materials from which the piping and vessels are made
- ▶ High cost of extensive testing at high pressure
- ▶ Ignorance of practical high-pressure operation
- ▶ Secrecy restrictions.

HOW HIGH IS HIGH PRESSURE?

The top limit is cost. The lower limit is an arbitrary 10,000 psi, below which conventional techniques and equipment apply. Above that, the special problems of high pressures become important. In addition, apparatus for operation above 10,000 psi usually is specified to withstand one application of test pressure. The user decides the test pressure by balancing apparatus life, actual operating pres-

3 WAYS TO MEASURE HIGH PRESSURE

Primary Element	Range	Dynamic Response	Calibration	Application Remarks
Mechanical: Helical, Bourdon	Up to 80,000 psi	Not known	<1 percent hysteresis; 2 percent change per 100 deg F	Operates alarms, signals, other overrange devices. Or motion is transmitted pneumatically or electrically to operator's panel.
Electronic: Strain cell	Up to 50,000 psi	Depends on electrical instrument	Inaccuracy $\pm\frac{1}{4}$ percent of full range. Fully temperature compensated.	Excellent primary element for continuous control backed up by mechanical elements linked to a standby control system.
Electronic: Bulk-Compression Cell	Up to 200,000 psi	Determined by fluid viscosity	Linear with pressure; temperature-sensitive	Employed as: 1) Primary measuring element. 2) Secondary standard mounted in a constant temperature bath

sure, margin of safety, and the pressure ranges of the rest of the processing equipment.

Differential Pressure

Where the pressure difference is of the same order of magnitude as the static pressure, the outputs of two pressure springs, two strain cells, or two bulk-compression cells are differenced. But as the ratio of the differential to the static pressure decreases, errors progressively increase.

Low differential is measured at high pressure by the inductive cell, assembly shown in Figure 5. It has passed laboratory tests at 50,000 psi.

Motion

The inductive pickup assembly developed for the differential-pressures cell offers a general method for motion measurement within high-pressure vessels. Minimum motion for full scale output is 0.010 in. Motions up to one foot should be possible. Design recommendations:

- ▶ Length of ferromagnetic slug ≧ measured motion
- ▶ Coil structure ≧ twice measured motion
- ▶ Tube proportionately longer

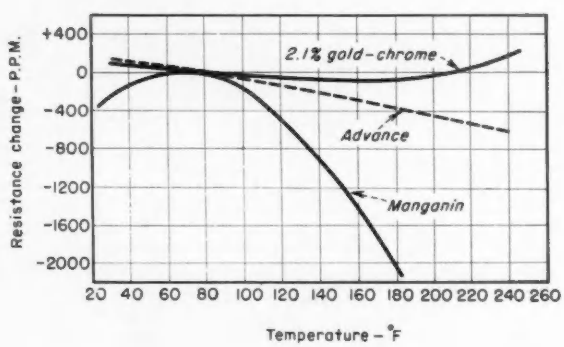
Pressure Standards

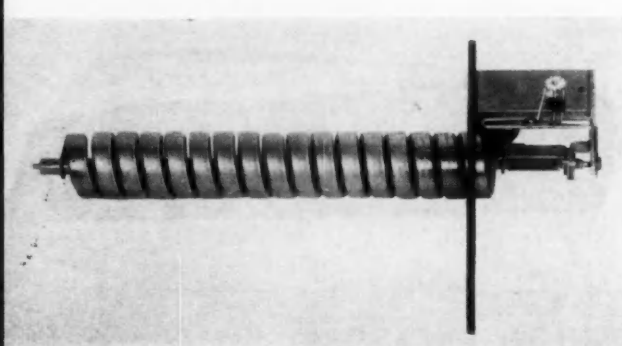
Up to 50,000 psi, the standard is a dead weight

(continued on Page 56)

The specific resistance of most metals changes when subjected to fluid pressure. Varying greatly between materials, the effect is small compared with the change in resistivity with temperature, as the illustration shows. Temperature sensitivity is high at elevated pressures because the fluid's compression is adiabatic. Thus a transient temperature change results from a pressure change, even when a constant-temperature bath surrounds the assembly.

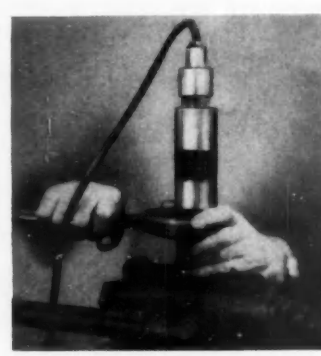
The cell uses a fine wire of manganin or gold chrome. Although manganin has the higher absolute pressure coefficient of resistance, a properly treated gold-chrome wire has the greater ratio of pressure coefficient to temperature coefficient and is therefore the preferred material. FIG. 3





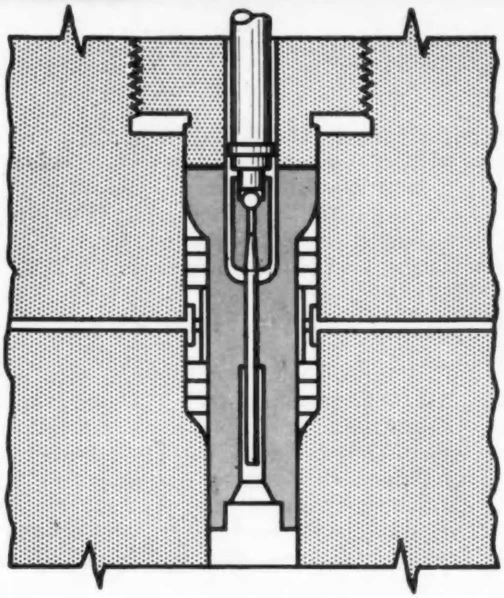
Bourdon pressure springs specifically designed for high-pressure use are the safest and most reliable. The material is type 316 stainless steel, chosen because of its resistance to corrosion and to strain-embrittlement. Fabricated from tubing with a high ratio of wall thickness to inside diameter and with a limited flattening, the deflection per coil is extremely small. Therefore, a large number of coils increase rotation and minimize the multiplication of the linkage between spring and indicator or recording pen.

Heavy cold working in drawing, forming, and coiling plus pressure autofrettage above rated pressure provide adequate spring properties. FIG. 1

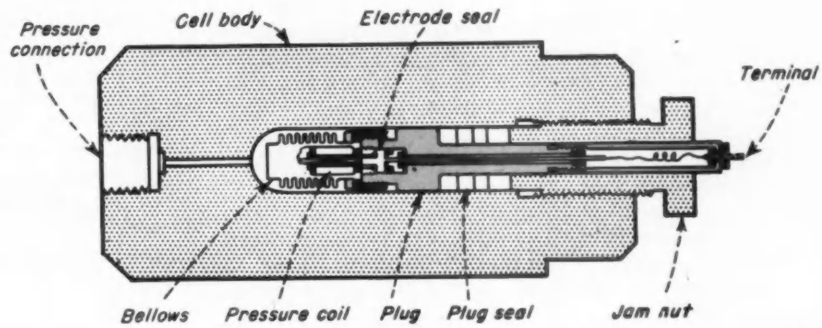


The strain cell manufactured by Baldwin-Lima-Hamilton consists of a rectangular block with a cylindrical hole into which the pressurized fluid is admitted. Two pairs of strain gages arranged in a Wheatstone bridge measure the block's distortion. Connection of one pair of gages in compression and the other pair in tension compensates for temperature changes.

At rated pressure the cell develops one millivolt output per volt applied across the bridge. It is used with standard self-balancing electronic potentiometers, with portable strain indicators, and with Brush, Sanborn, and similar amplifier-recorders. FIG. 2

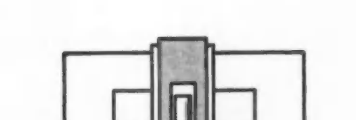


Superfinished piston and sleeve are accurately fitted. The relatively thin sleeve mounts in a larger supporting block between two Bridgman packings. The fluid admitted to an annulus surrounding the sleeve is controlled to previously calibrated pressures to adjust the piston clearance. The controlled clearance allows free piston motion with a minimum of leakage and facilitates accurate computation of the piston's effective area. A dead-weight tester of this type responds to weight changes of less than 1/100 of 1 per cent of total loading and leaks as little as one cubic mm per min at 100,000 psi. FIG. 6



Gold chrome wire, loosely wound to avoid mechanical strain and the accompanying strain-gage effect, is sealed in a bellows filled with kerosene. A single wire passes through a lead-in seal. The unit mounts in a cavity in a block designed to avoid stress concentrations. A conventional Bridgman unbalanced-area pressure seal closes the block.

Most critical is the insulator structure for the lead-in wire. Glorified spark plugs suffice up to 50,000 psi. There is need for further development of insulators above this pressure. Porcelains, "pipestone," and agate insulating sleeves are in use. FIG. 4



Differential pressure applies across a bellows or a diaphragm, opposed by a spring. The bellows moves a ferromagnetic slug inside a stainless steel tube with a thick wall. A coil around the tube detects the slug's motion. By using a heavy-walled stainless steel bellows and appropriate stops, the device can stand an average differential pressure of 1,500 psi in either direction. It can be equipped with a rupture disc in anticipation of greater over-range differential pressures.

The cell operates at 1,000 cycles ac. Only the structure and the connecting piping limit the dynamic response. Full temperature compensation is available. FIG. 5

tester structure comprising a piston accurately fitted and lapped into a supporting sleeve and loaded with dead weight. At 50,000 psi, more than a ton load hangs in a cage supported by a ¼-in. piston.

As the measured pressures increase, elastic deformation of both piston and sleeve increase proportionately. It becomes difficult to maintain a clearance without excessive leakage of the test fluid or seizing at lower pressures. Limited choice of hydraulic fluids further complicates the problem. Lubricating oils solidify at pressures slightly below 100,000 psi. The water-base hydraulic fluids, with their viscosity increased by addition of organic compounds, do not solidify, but they are not good lubricants.

The "controlled-clearance piston" illustrated in Figure 6 was developed to overcome these problems.

TEMPERATURE

Because the relation between temperature and pressure is a prime controlling factor in high-pressure operations, accuracy in temperature measurement is fully as important as in pressure measurement. Three types of elements are in common use: the thermocouple, the resistance thermometer, and the filled mechanical system.

Bare thermocouples of wire sufficiently heavy for adequate mechanical strength sacrifice rapid transient response. An experimental form consists of a concentric tube and core made of the two dissimilar thermocouple materials. After the annulus is packed with insulating powder, the co-axial structure is drawn down to the desired diameter. It forms a stiff tube which can be sealed through the vessel wall with a conventional packing. Long enough to extend out of the vessel, it provides its own insulation.

A neglected high-pressure temperature element is the mechanical vapor-pressure thermal system. The bulb can consist of a short length of 0.020 x 0.060 capillary. Standard type 316 stainless steel tubing of this dimension is available. It has a high strength and it mounts readily either just off the wall of the vessel or on a coiled form. The connection through the vessel wall would be through a tubing of even smaller bore, say 0.010 in., running 5 ft or less to a measuring instrument with a pneumatic or electric transmitter. Because of the small outside diameter of the measuring tubing, the response is extremely fast. Because it depends on vapor pressure, small changes in the volume of the system due to pressure have no effect on the reading. Should the measuring tubing develop a leak, fluid flow through the lead-in capillary would undoubtedly blow up the pressure element. Even at high pressure, however, the rate of leakage of the material in the vessel through a 0.010 capillary hole would be so small as not to be a serious hazard. Furthermore, this flow can be pinched off without shutting down the process. The cost of replacing the measuring capillary, lead-in capillary, and pressure element would be comparatively small. This device has important possibilities both as a primary high speed measurement and also as a backup for other types of measuring systems. It can operate electrical or pneumatic signals and alarms. It involves no vacuum tubes. It is new and has been applied only experimentally to date.

LIQUID LEVEL

Measurement of liquid level at high pressure is less well developed and less conventional than measurement of pressure and temperature. It is almost impossible to design a free float that will withstand the pressure. Displacement floats are extremely expensive because of the valuable space required. And they are sensitive to pressure variations of the vapor above the liquid.

Electrical capacitance has been quite successful. Figure 8 shows an installation. A straight rod running the length of the vessel is insulated if the measured liquid conducts. The rod can be bare if the liquid insulates.

Gamma-ray measurement of liquid level is a definite possibility. The heavy vessel walls involved in high-pressure operation require a strong source of radiation and correspondingly good shielding to protect personnel. The source may be inside the vessel, in which case the vessel walls provide considerable shielding. However, this case requires special techniques when the vessel is opened for maintenance or service. On the other hand, the source may be placed on the outside, with the radiation passing in through one vessel wall and out through the opposite vessel wall. [CONTROL ENGINEERING, Vol. 2 No. 3, discusses application of radioactive elements.—Ed.]

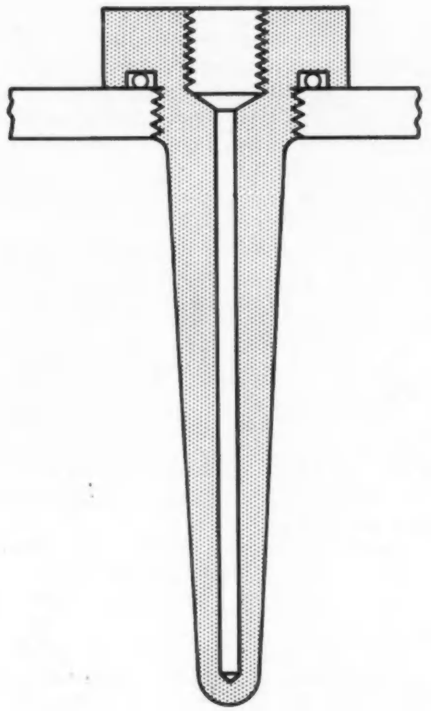
Sonic level measurement has been proposed. The sonic elements could presumably be placed at the bottom of the pressure vessel. Measurement of the time for the sound wave to travel upward to the surface of the liquid and reflect back down either to the same or to a separate element would give a measure of level. There is every reason to believe that magnetostriction devices should operate satisfactorily under high pressure. Data on crystal units under these conditions is limited.

FLOW

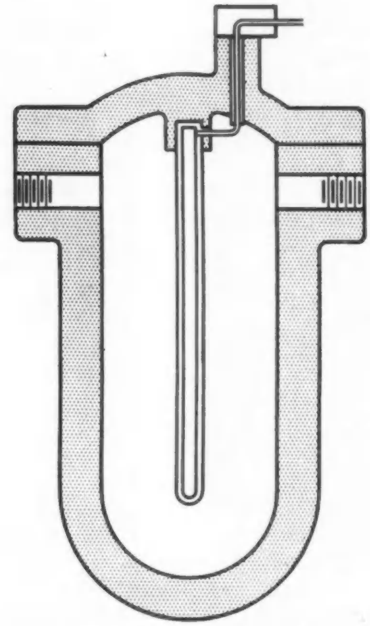
Flow measurement at high pressures is highly desirable, if for no other reason than to provide a signal for stabilizing the process after faulty operation of pump valves. The problem is not inherent to high pressure as such, but is due to the fact that in practically all production operations the fluid is pumped by reciprocating plunger pumps, developing a violently pulsating flow.

Using an orifice, a pulsation plus or minus 20 per cent from average flow causes a reading error of about 2 per cent in a differential pressure element.

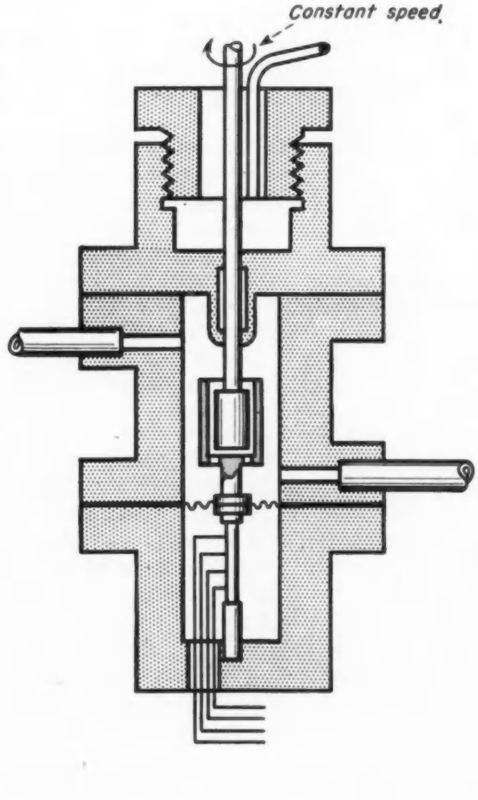
If a triplex pump operates perfectly with no valve



In high-pressure operation the convenience of mounting the element in a suitable socket is important. On the other hand, sockets that withstand the pressure are heavy and expensive. Their wall thickness materially retards transient response, a significant disadvantage in high pressure reactions with rapid dynamics. A special small wire thermocouple fitted into a socket with an i.d. of $\frac{1}{8}$ in. and an o.d. of $\frac{3}{8}$ in. minimizes this disadvantage for the 50,000 psi range, especially if the tip of the socket is made at least as thin as the wall and the thermocouple presses firmly against the bottom of the hole. FIG. 7



The capacitance probe mounts independently. A small lead wire is brought out through an insulating bushing. Even with a small wire it is difficult to maintain a low and constant bushing capacitance. FIG. 8



A suggested shear measurement of viscosity: An external motor would drive a cylinder at constant speed through a "controlled-clearance" seal. A strain gage would measure the torque exerted through the liquid on a cup surrounding the liquid. By design, this entire mechanism could be subjected to the high pressure. Only the lead wires would pass through the vessel wall. Like most high-pressure apparatus, its performance would depend upon detail mechanical design. FIG. 9

leakage whatsoever and pumps an incompressible fluid, the theoretical variation in flow rate is only plus or minus 7½%. At the other extreme, pumping a gas produces a flow variation of 100 per cent during each cycle. At high pressure, liquids are appreciably compressible and pumps do not operate in a theoretical manner. As a result, the flow fluctuates enough to seriously upset absolute calibrations. If the pattern of flow fluctuation is nearly constant, a well-damped differential-pressure meter introduces a constant error. The meter then measures flow variations quite satisfactorily if calibrated in service.

The same considerations apply to other primary elements. A variable-area meter (rotameter) with an inductive takeoff similar to that described under differential-pressure measurement has a wider rangeability than an orifice.

Thermal flowmeters have been suggested. Operated at lower pressure with a constant temperature differential maintained by controlling the heating element, the heat is supplied directly proportional to flow. For pulsating flow, it is necessary to surround the heating element with a volume equal to several times the displacement of a single stroke of the pump piston in order to get a good average-flow reading. If large flows are measured, the power input is considerable to produce temperature differences suitable for accurate measurement.

Counting of pump strokes is a common method of measuring flow. It is reasonably accurate when pump valves operate properly. The high pressure proportioning pump is in this service.

AND . . .

Other measurements at high pressure, such as density and viscosity, are purely speculative. Gamma ray measurement of density would operate under favorable conditions because the measuring head would presumably be oriented horizontally.

Because viscosity is an excellent measure of the conduct of high pressure reactions, its measurement is potentially important. The high-frequency vibrating reed viscosity unit (the Ultra-Viscoson) should operate satisfactorily at high pressure with some detail structural modifications. It also is practical to measure absolute viscosity by shear, Figure 9.

CONTROL

Control of high pressure reactions presents problems easily recognized but not so easily solved. While present controls are reasonably adequate and are steadily improving, there is considerable to be desired in this field. Problems arise from three sources:

▶ The dynamics of high pressure processes are "difficult." Favorable capacity of most high-pressure systems is small and the circulation rate is high. Thus, in many cases the reaction rate is high. High-pressure operations, even in liquids, are adiabatic. That is, increase in pressure produces a corresponding increase in temperature, in turn tending to accelerate reaction and further increase pressure.

▶ Measurement problems are serious. Reliable temperature measurements with good dynamics are difficult. Flow control, the backbone of most continuous processing, is complicated by pulsating flow. While flow-measuring apparatus for high pressure is expensive, greater use of flow control will be made.

▶ High-pressure apparatus does not lend itself to control. Service on high-pressure pumps is severe with a history of large and sudden disturbances due to malfunction.

Valves, Seals, Pumps

Heavy valve bodies made of strong material handle the operating pressures. The valve trim is made of high-strength, high-hardness material to withstand the erosion of high-velocity flows that occur because of big pressure drops.

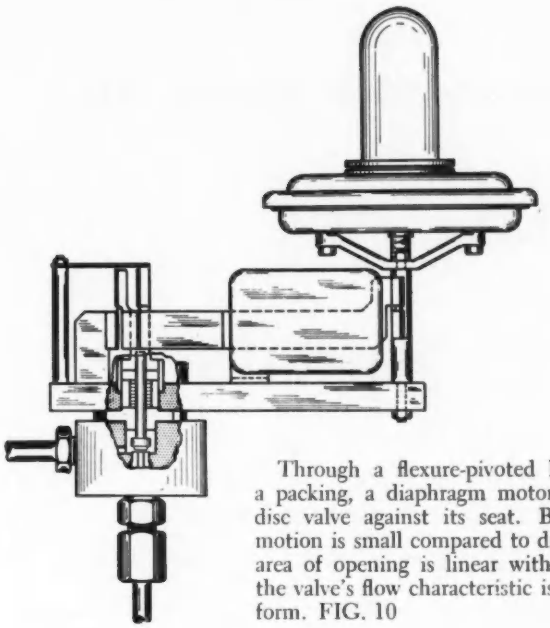
Tight shutoff calls for single-seated valves. Because these valves develop large unbalanced forces at the usually big pressure drops, precise and rapid valve positioning requires highly specialized, and frequently very expensive, valve motor operators. Figure 10 illustrates a commercial valve and operator assembly.

The controlled clearance assembly, originally developed as a necessary feature of a high-pressure dead-weight testing unit, presents a number of opportunities in high-pressure control. It can seal both linear and rotary motion. By varying the seal pressure in the annulus, the flow of liquid or gas can be controlled. Since the increase in diameter of the piston and sleeve increases not only the peripheral length of the path but also the permissible change of clearance between piston and sleeve control of considerable quantities of flow by a structure of this type appears entirely feasible.

Particularly where an active control produces continuous valve motion, the problem of a packing with negligible leakage, low friction, and long life is a serious one. Figure 11 shows a novel packing design.

The intensifier pumping system shown in Figure 12 has been suggested for high pressures. Aside from its merits as a pump, it has important characteristics that facilitate automatic flow control.

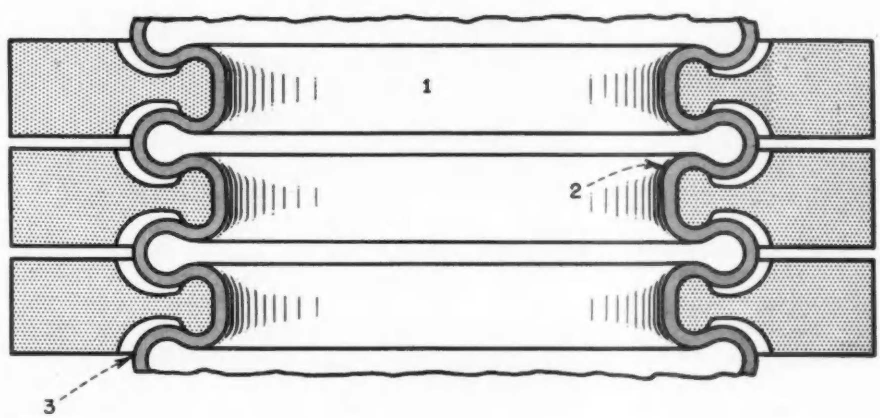
High-pressure control systems take full advantage of compound and cascade control mechanisms. Rate action is used either in a continuously throttling controller or in overriding and limiting mechanisms. Most controllers are pneumatic. Their transient response is adequate when compared with those of the available measuring elements (particularly temperature) and with those of the final control elements (valves, etc.). Facilities for control analysis and experimentation under high pressure conditions are limited. Particularly in this field the secrecy restrictions become limiting. Improvement of control at high pressure presents large opportunities for control engineers.

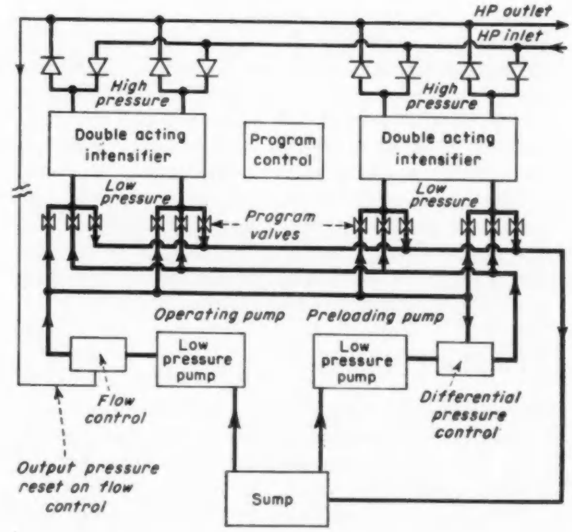


Through a flexure-pivoted linkage and a packing, a diaphragm motor operates a disc valve against its seat. Because disc motion is small compared to diameter, the area of opening is linear with stroke and the valve's flow characteristic is nearly uniform. FIG. 10

A stack of collars (1), supports the inside of each convolution of a triple-walled metal bellows (2). In fabrication, the bellows is drawn hydraulically over the inside of the collars. Internal pressure develops uniform tension in the circular, unsupported section (3). External guides prevent buckling of the bellows. Bellows constructed this way have withstood 30,000 psi. Pressurized to 10,000 psi, they have successfully undergone 30,000 cycles of elongation and contraction with 0.003 in. per convolution.

Friction is negligibly small compared to the friction of a conventional steam packing. The force required to move the bellows is a small fraction of the force required to overcome the pressure drop across the valve. A valve, such as the one shown in Figure 10, using the seal will undergo field trials shortly. FIG. 11





The "pipless" intensifier pumping system consists of two double-acting intensifiers, i.e. differential-area pressure boosters. A flow control on the low-pressure side causes the high-pressure fluid to discharge from the operating cylinder at a constant rate. While one cylinder discharges (and its opposite cylinder fills), the second intensifier brings the fluid in its discharge cylinder up to nearly the full discharge pressure, taking up all compressibility in advance. When the working cylinder reaches the end of its stroke, it trips a cut-over mechanism, transferring the constant low-pressure flow to the second intensifier. Since this second intensifier is already preloaded to working pressure, the discharge flow during transfer continues at a constant rate. A sequencing system then shuts off the first cylinder and in turn reverses it, preloading the cylinder just previously filled. Thus a continuous cycle of steady flow occurs.

Any desired reactor variable can monitor the flow. The system has considerable possibility where fast, smooth control is of major importance. FIG. 12

Make the Most of Good Components

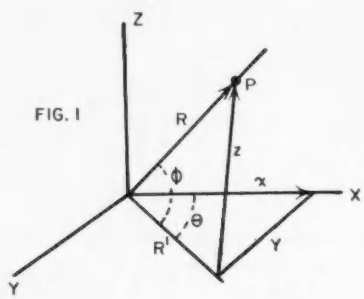


FIG. 1

To build an accurate ac analog computer you have to start with excellent components. But how you connect them is just as important. Here are some exemplary synthesis techniques used successfully in a gun-fire-control computer.

CHARLES D. BOCK, American Boscsh Arma Corp.

A two-resolver computing combination shows how neatly ac components can be combined to handle problems in three dimensions. The inputs are the three rectangular coordinates x, y, z, at the point *P*. The computer is required to give the polar coordinates θ, ϕ, R of the same point *P* as its outputs, Figure 1.

Two resolvers, arranged as shown in Figure 2, will effect this transformation. The resolver R_{B1} performs the vector addition of the x and y distances to give the plane polar coordinates θ and R' in the XY plane. Using R' and z for the inputs to resolver R_{B2} adds the vector z to R′ to give the coordinates *R* and θ.

This problem is a perfect analog of a gun mount problem in which θ represents the train angle of the mount and ϕ the elevation angle. "Perfect" means that there is no design approximation involved; more accurate components will give more accurate results. This condition is often referred to as a "Class A" solution. A "Class B" solution would use a different mathematical function to approximate the desired function over a limited region, and its accuracy would have designed-in limitations.

The same computer is shown in more detail in Figure 3. The inputs are shown as handcrank and dial. Most military computers would need automatic inputs, which may require servos to give faster input variation. P_1—P_4 are shown as potentiometer units, with their constant voltage inputs from a single voltage source. Isolation amplifiers AB_1—AB_4 eliminate loading errors that result from drawing current from the computer units.

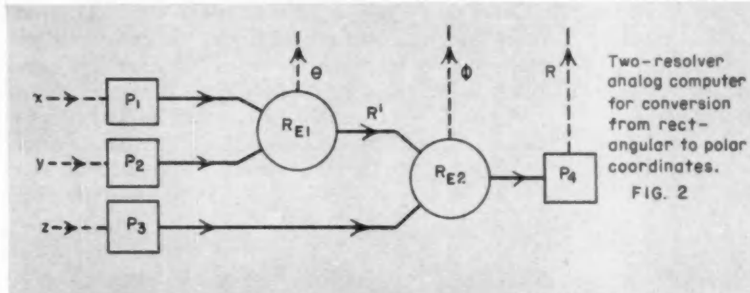
Output servos to make the solution automatic are shown, as they are nearly always required, especially in computers of the regenerative type, where successive approximations are necessary. The automatic analog computer carries these out about as fast as straightforward solutions, provided the computer is properly stabilized. Such a computer will be described in a later article in this series.

The following discussion assumes that the highest possible accuracy must be realized. As resolvers and potentiometers are available to average errors of a few parts in 10,000, many precautions are necessary to take full advantage of such accuracy.

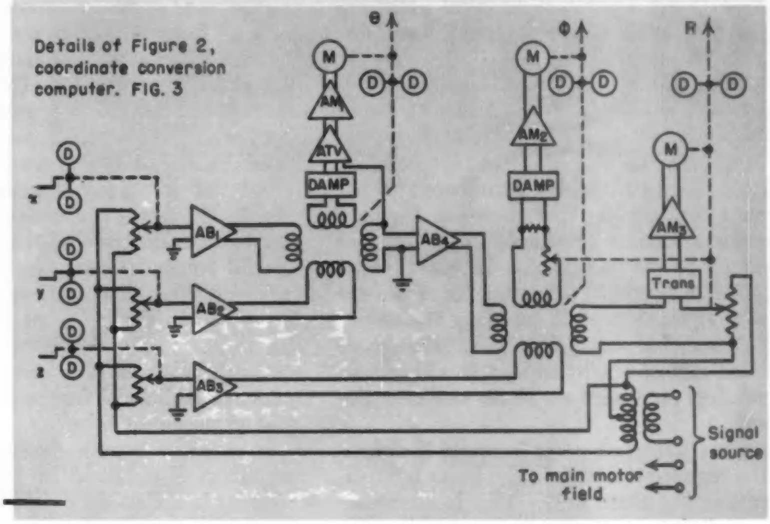
SIGNAL INPUT

The exciting voltage source for the input computing components should meet definite specifications to achieve full accuracy in the outputs without undue complication.

The choice of frequency should depend on these



Two-resolver analog computer for conversion from rectangular to polar coordinates. FIG. 2



Details of Figure 2, coordinate conversion computer. FIG. 3

considerations:

- ▸ Servomotor torque-to-inertia ratios are best at lower frequencies. They are satisfactory at 60 to 400 cps. Much above this band it is necessary to demodulate the null signals and use either dc or a frequency inside this band to drive the servomotors.
- ▸ Wiring problems are minimized in this frequency band. Higher frequencies give more trouble from capacity loading and circuit cross-talk.
- ▸ Components, especially resolvers and the isolation amplifiers, may be designed for a single frequency or a specific band.
- ▸ A special source of this voltage may be necessary to meet the requirements of wave form and frequency tolerance. Where it is practical to keep the harmonic content below 1 percent and the frequency variation to plus or minus 2 cps, this input perfection may pay off in simpler servo designs. Sufficient power should be available, preferably at quadrature phase to excite the main field of ac induction servomotors.
- ▸ Lower frequencies, even inside this band will increase the size and weight of transformers and hence of the amplifiers.

It is convenient for testing and trouble shooting to have hand inputs and dials of sufficient accuracy to avoid significant reading errors.

The input potentiometers, P_1, P_2 and P_3 fortunately must satisfy only the accuracy requirement for resolution unless severe smoothness is demanded at the outputs. The output potentiometer, P_4, on the other hand may need much higher resolution, or the servo will oscillate between wires when its sensitivity is high enough to avoid servo errors. The output resistance of the input potentiometers will be limited by the input specification of the isolation amplifiers AB_1, etc.

ISOLATION AMPLIFIERS

To reach the resolution required for accuracy of a few parts in 10,000, resistance of thousands of ohms is necessary in potentiometers of conventional design. As the resolver input impedance is about 1,000 ohms—which can be raised to perhaps 6,000 by tuning with a shunt condenser—the loading would produce errors many times the allowable value. Replacing the potentiometers with inductive potentiometers now available in England and here (e.g., Perkin-Elmer's Vernipot) would greatly reduce loading effects. But all available resolvers require isolation amplifiers for the highest accuracy. Without these amplifiers loading errors run an order of magnitude larger.

Isolation amplifiers (sometimes called "booster amplifiers"), designed so that they do not contribute errors of themselves, about call for feedback

of a high order. Tube specifications allow about 10 per cent variation of gain in new tubes, and this gets worse as tubes age. But the lowest error requirement calls for gain variations not over 0.01 per cent from this source.

This increase in accuracy can be attained on a reliable, interchangeable basis by using negative feedback of about 70 db.

The gain required for this amplifier is not difficult to get, but rather careful design and development is needed to get stability at such a high feedback ratio. The engineering concepts most useful in developing such amplifiers have been those of Bode and Nyquist.

Bode[1] showed that all the information about circuit stability is available in the attenuation-vs-frequency function of the circuit in open loop. A simplified approach to this concept is given by Terman in his "Radio Engineers Handbook."[2]

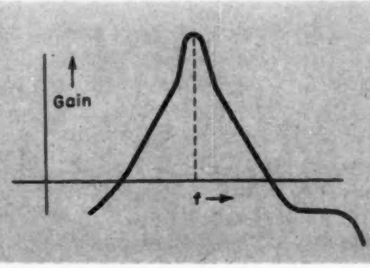
A frequency response like that shown in Figure 4 is desirable for a booster amplifier. A cut-off rate just short of 12 db per octave should stay clear of instability. It is wise to take advantage of resonance peaking and sharpen the cut-off rate near the carrier frequency. Since the phase shift is an average of the attenuation rate of nearby regions, it will remain less than 180 deg. even with an 18 db rate near the resonant peak.

A shelf in the attenuation curve increases the phase margin in the regenerative region; the lower attenuation rate reduces the phase shift. This is necesssary only in the high frequency end, since that is more sensitive to stray lead capacitance.

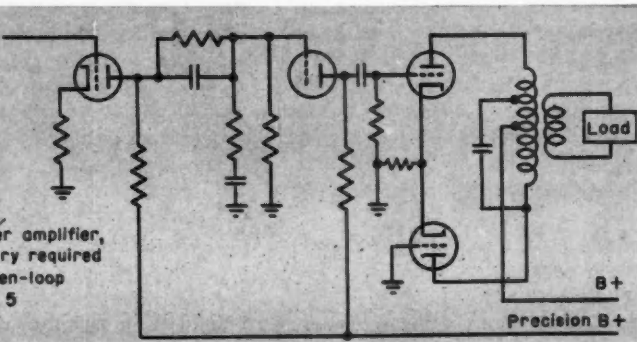
Figure 5 shows a typical amplifier circuit that obtains the required open-loop response. Note the parallel RC coupling between stages 1 and 2. This gives cutoff limited to a frequency band, and can be designed to avoid overlap with the next coupling circuit. The location shown is preferable because it is risky to put a possible bias-raiser in power tube grid circuits. The coupling capacitor to the power tube is large to extend the low-frequency cutoff. Basic cutoff shaping is achieved in the output transformer, which with the normal inductive load, gives a Q of about 5. Series resistors in all the high frequency cutoff elements keep their effects from adding at high frequencies. Conventional phase inverters have very poor cutoff characteristics, so a grounded-grid system is used here. Care must be used in the output transformer design to avoid effects of its high-frequency cutoff. In fact, all the design values of the networks will depend upon the transfer function of the output transformer and special precautions are necessary in its design.

The feedback connections may be either grounded input, as in Figure 6, or grounded output, as in Figure 7. For compensating the poor transformer characteristics of the induction computing components, additional feedback may be inserted at the grid of the input tube.

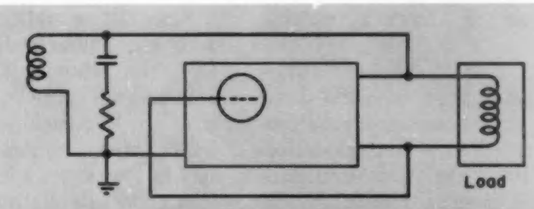
In another system developed in England, compensation is obtained by incorporating a feedback winding in the resolver. Then no output transformer should be used in the amplifier, because it is very



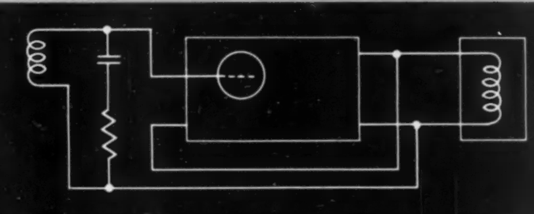
Frequency response characteristic required for a stable booster amplifier for AC resolvers. FIG. 4



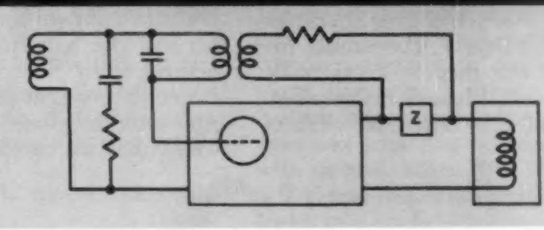
Typical booster amplifier, showing circuitry required for proper open-loop response. Fig. 5



Feedback loop closed — grounded input. FIG. 6



Feedback loop closed — grounded output. FIG. 7



Feedback loop closed — current feedback to special winding in resolver. FIG. 8

difficult to allow for the cutoff of two transformers each of which gives an asymptotic cutoff of 6 db per octave for low frequencies, with a sharper cutoff of 12 db above the coil resonance frequency.

These amplifiers are sensitive to external circuit constants. Capacitance to ground in the grid circuit increases the cut-off rate for high frequencies and will reduce the margins. However, 400-cps amplifiers can be made to tolerate 10,000 micromicrofarads.

The high-frequency cutoff rate is difficult to maintain, because all wiring tends to give capacitive loads that produce 6 db per octave cutoff in combination with each tube's internal impedance, or at least with the leakage component of a transformer.

The low-frequency cutoff is sensitive to the load. If the series resistance of an inductive load is too low, the low-frequency cutoff will sharpen at very low frequencies and instability will result.

Special precautions must be taken in the current feedback circuit, Figure 8, to avoid unstabilizing effects. Since the current feedback is positive and increases at low frequencies, it can retard the bass cutoff to the point where basic amplifier cutoffs become too steep. This circuit must be made band pass in type, as shown.

Inductance in the grid circuit must be bypassed also, or its high-frequency cutoff will unstabilize the amplifier, since the grid-circuit capacity forms an LC filter. A resistor, Figures 6-8, reduces the resonance peak of the resolver coil, which would give undue amplification to the resonant frequency. Also the resistance of the input signal source must be limited or the stray capacities of the grid circuit will unstabilize the amplifier.

Despite these limitations, which may be considered the price of high accuracy independent of tube characteristics, these amplifiers are very reliable and strictly interchangeable. While this high feedback gives an increased tolerance for tube deterioration, tests are needed that are sufficiently sensitive to show normal tube conductance decay, such as measurement of the amplifier's input grid voltage. Otherwise normal decay of tube performance will act like a catastrophic failure because early warning is masked by the feedback.

Similar effect is produced by overload. If the amplifier saturates before it has put out the required voltage, very large errors result. Since feedback does not function under these conditions, there is very little increase in useful output by the use of feedback. In fact, it is necessary to design conservatively on power output. The most conservative design would require a nominal output voltage capability about twice the required value. Then a decay in maximum output from the nominal value will not disable the computer so soon, and we can expect reasonable life from amplifiers.

COMPUTER SERVOS

Consider next some servos that might be used for this computer. Of the many possible, two common classes are useful. Figure 9 is a diagram of an error-rate-damped servo using an ac network to get the

damping function. Figure 10 shows a velocity-damped servo.

The type of servo has much to do with synchronizing performance. The faster servo with the least dynamic lag is provided by error-rate damping. Saturation effects are more severe than in the generator-damped servo of Figure 10. Saturation suppresses the damping in Figure 9; but in Figure 10 the generator voltage matches the error signal, to extend the non-saturating operating region.

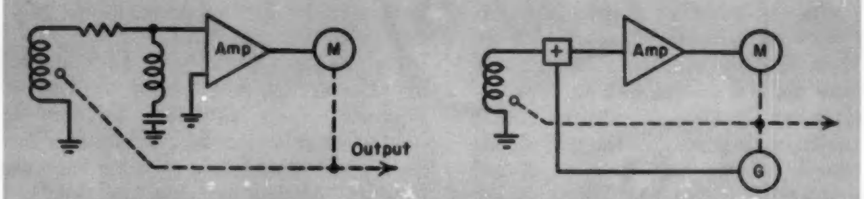
Friction or viscous drag can stabilize servos. Coupling thus to ground produces dead-space errors in the former case, or velocity lags in the latter. Coupling to a flywheel makes the servo more analogous to the error-damped case of Figure 9, but slows it down because of the added inertia.[4]

The ac network of Figure 9 is operable in a narrow band of frequency only. ΔF, the error in carrier frequency must be smaller than F, the natural frequency of the servo, or else there is considerable deterioration in performance. Phase shift shows first, and it may be compensated by a suitable shift of the main field phase.

Since all ac addition in linear networks is vector addition, phases must be kept very accurately—in fact, the ratio of phase-to-magnitude error allowable without special quadrature suppression is usually less than 4. Synchro specifications have been held to 0.2 by servo-conscious engineers, but that is unnecessary in low-power computer servos.

A good rule of thumb considers the highest useful gain that at which the amplifier output voltage drops to about 70 per cent of maximum, if the residual input is quadrature, but usually less if the residual is harmonic.

Quadrature residual in the null is one of the most frequent causes of servo error in the computer. Ideally the two-phase servomotor is an excellent phase discriminator since it yields zero torque with in-phase fields on its alternate poles. But there are limits in ability to control phase. The motor amplifier will give some phase shift and the ac damping network shifts phase with variations of signal carrier frequency as well as with any errors in its own tuning. Any error in phase makes the servo yield torque which must be compensated by an offset until the



Servo using AC network for error-rate damping. FIG. 9

Servo using induction generator for rate damping. FIG. 10

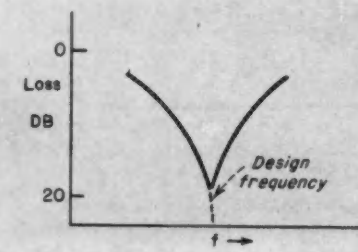
in-phase null error yields an equal and opposite torque. Hence other methods of damping are preferable for the most precise work.

The designer pays an added price for the use of the ac network. Damping requires a notch-type filter, Figure 11, with the carrier at the lowest gain point. A common loss is near 20 db; hence the noise and harmonic content are exaggerated about 10 to 1. More complex networks can be used to avoid part of this trouble, but it is more practical, in general, to control signal purity. Hence, the highest gain useful is limited by signal impurities.

Quadrature is another signal impurity. Much effort is necessary to avoid saturation of the amplifier with quadrature. Since the frequency is the same as the carrier, quadrature is fortunately not exaggerated in the lead network. But it requires close specifications on signal phasing to keep its magnitude under control.

Where quadrature is too large for the direct servo performance needed, a frequency converter can be made for quadrature elimination. In a demodulator-modulator circuit the tolerance for quadrature is related to the phase accuracy of the preamplifier, and it should have feedback to stabilize its shifts. Phase-shift error in the circuits of this converter and its preamplifier changes some quadrature into in-phase, which offsets the servo. The requirements are stiff if large quadrature voltages must be handled.

It is very difficult, if not impractical, to use this modulator scheme unless the frequency is raised. The cost of smoothing the rectified signal is too



Notch-type frequency transmission needed for AC network damping. Figure 11 exaggerates noise and harmonies.
FIG. 11

much deterioration of damping, because of the inherent delay in filters, to allow enough attenuation to avoid direct signal feed-through. Changes from precision to crude supply at the same frequency will therefore result in beating and should be avoided.

Figure 12 shows a quadrature elimination circuit. Here the amplifier is given negative feedback through a non-linear network that passes only quadrature. The effectiveness here also is limited by the amplifier phase steadiness.

A good servo amplifier should have considerable negative feedback to stabilize its gain, both in magnitude and in phase. It is convenient to use this feedback circuit to adjust the gain on standardized computer servo amplifiers. Large corrections of phase shift should not be made in this manner, however, because the correction vanishes in saturation when synchronizing to a large signal. Here the sum of the saturation shifts of the amplifier and the loss of this correction have been known to exceed 90 deg, thus stalling the servo.

The servos of Figures 9 and 10 both change damping with gain. Referring to the second order differential equation, which describes the simplified servo,

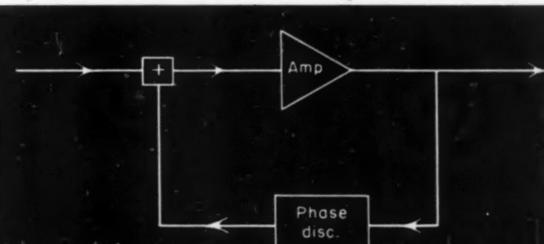
$$I\frac{d^2\theta}{dt^2} + R\frac{d\theta}{dt} + L\theta = 0$$

where I is the inertia, R the viscous damping coefficient, and L the torque gradient, critical damping is defined by the condition of two equal roots, where $R^2 = 4IL$. In the case of Figure 9, error-rate damping, the magnitude of R always varies directly with that of L. Hence, decrease of signal level decreases the damping, whether the change in servo gain comes from the computer configuration or from the change in amplifier gain. In the case of Figure 10, generator damping, change in amplifier gain gives the same effect but change in gain due to computer signal level changes produces the reverse effect, since here L changes alone. If the damping is done mechanically,[5] the effect is like the second case, and reduction in gain will give overdamping, with sluggish action.

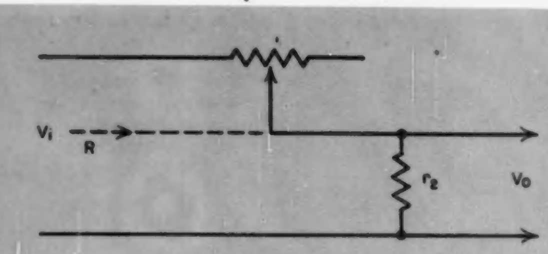
To avoid these changes in servo performance, automatic gain controls are needed. These can be mechanically operated resistor dividers, if a mechanical analog is available to drive them.

Servo S_2 of Figure 3 has a mechanical drive in the R output, which is proportional to the excitation of R_{E2}, and therefore to its angular sensitivity or voltage gradient. A suitable non-linear potentiometer, one with a gain proportional to $1/R$, meets the requirement. So does a linear variable resistor in series with a small constant resistor as shown in Figure 13. Here $r_1 + r_2$ should be proportional to R. Hence r_1, should have its maximum value larger by the ratio of R_{max}/R_{min}. A compromise is usually acceptable in the region of small R, to reduce the strain on this requirement. In any case we cannot solve for θ or ϕ too near $R = 0$.

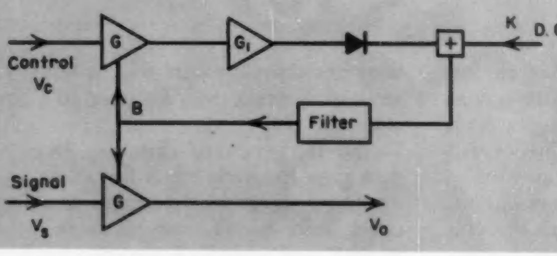
Where no mechanical drive is available, or where the control range is difficult to get in a potentiometer, an electronic attenuator is necessary. Figure 14 shows such an automatic gain control. Two pentodes are used in the circuit. Assuming that they have matched grid-bias cutoff curves, the input



Phase discriminators can be used for quadrature elimination.
FIG. 12



Non-linearity of simple resistance divider can keep servo damping almost constant as input varies. See text. FIG. 13



Electronic automatic gain control for making servo damping independent of input signal level. FIG. 14

V_c is amplified the same as the signal V_s. If G is the variable gain, $V_o = GV_s$. Since the control amplifier is fed back for constant output, approximately $GG_1 V_c - K = B$, the bias voltage. If B is small compared to K we have $GV_c = \frac{K}{G_1}$, ($B << K$); or we can write $G = \frac{C}{V_c}$.

Now if V_c is proportional to servo sensitivity S, $V_o = \frac{CV_s}{S} = \frac{aS}{S} = a$, independent of the computer sensitivity.

Matching the tubes violates a principle of good electronic engineering practice. A screen voltage adjustment, however, can match two points in the gain curve. Then even different types of tubes can be made to give plus or minus 50 per cent gain constancy to the servo, which usually is good enough. These devices have been successfully operated over a 1,000 to 1 range, although 200 to 1 is a conservative requirement. This performance is difficult to match in a mechanical potentiometer, even if a shaft is available.

Amplifier gain is likely to be very high to compensate for the loss of computer gain, so precautions must be taken to assure amplifier stability and freedom from saturation, since it is not likely that signal impurities will go down with sensitivity.

Another problem in small servo design should be mentioned—that of starting friction (the English call it stiction). To keep the friction error small, sensitivity is increased and saturation effects get worse. Since the natural frequency F goes up as the torque gradient L, trouble arises with servos of low inertia because of too high F. The limit is determined by the compliance of the gearing, whose cutoff frequency must be higher than F by several octaves. The obvious answer, then, is to add a flywheel to reduce F, but at a sacrifice in speed of response. In severe cases a friction-coupled flywheel known as a Lanchester damp may be used, with its friction adjusted to slip at saturation torque. Synchronizing time can be cut in half by this method.

Backlash in the gearing to the control element must be carefully limited for it will cause trouble if it is not small compared to the servo dead space.

Electro-mechanical integrators or speed-control servos are exceptionally sensitive to both backlash and gearing frequency-cutoff. If sensitivity of about 0.1 per cent of top speed is desired, either antilash gearing to motor or direct coupling through a large shaft must be provided. Note that in antilash gearing the drive depends on precision of the bearing, which acts as a fulcrum for the year that is really a lever-type drive. The bearing systems must be axially loaded to achieve an effective antilash gear drive even with spring-loaded split gearing.

REFERENCES

1. "*NETWORK ANALYSIS AND FEEDBACK AMPLIFIER DESIGN*," by H. W. Bode, D. Van Nostrand Co., Inc., 1945.
2. "*RADIO ENGINEER'S HANDBOOK*," by F. E. Terman. McGraw-Hill Book Co., Inc., 1943.
3. "*EFFECT OF FEEDBACK ON AMPLIFIER IMPEDANCE*," by R. B. Blackman, "Bell System Technical Journal," October 1943.
4. "*THEORY OF SERVOMECHANISMS*," by James, Nichols, and Phillips, M.I.T. Radiational Laboratory Series, McGraw-Hill Book Co., Inc., 1947.
5. "*INVESTIGATION OF A DUAL-MODE DAMPER STABILIZED SERVO*," by J. Jursik, M.I.T. Servomechanisms Lab Report No. 7138-R-4.

KEEP THE RIGHT KIND OF RECORDS TO

Protect Your Patentable Ideas

LEONARD H. KING, New York

Author King is a registered patent agent and an electrical engineer. He says protecting your inventions is much easier than most engineers think. It's mostly a matter of keeping comprehensive records—the kind you should keep anyway so that your fellow engineers won't have to repeat or duplicate your research. And for those who loath writing, he appends a streamlined disclosure form.

An engineer's notebook can be the stoutest bulwark in his patent protection procedure. But to serve this purpose it must be based on a realistic concept of patent law.

During a recent investigation of a patent situation, I asked an engineer about his record-keeping practice. "I record all the important data," he replied. This statement is a danger flag. How can a man know in advance what is to become important?

Consider an engineer working on one phase of a coordinated research problem. He is likely to record only what is directly related to his aspect of the program. And he may not bother with a mass of collateral data that may, however, be vitally important to the problem as a whole. As a result, he dissipates part of his knowledge, and he may also prejudice the project's patent rights.

Don't bother writing letters to yourself

Most laymen will glibly tell you that the best way to protect your invention is to send yourself, by Registered Mail, a sealed envelope containing the written description of the invention. Most authorities deny that such a record has practical value.

Actually, the best protection comes from conventional engineering records, including notebooks, engineering drawings, purchase orders, and project progress reports. An understanding of the procedures within the Patent Office will make clear how these records can be used.

After the application has been drawn up by the patent attorney and signed by the inventor, it goes to the Patent Office, where it is assigned to an examiner. He starts with what is termed a "novelty search." Here is the first stumbling point. The most frequent cause of rejection is that the examiner uncovers prior art, which may be in the form of a publication or a previously issued patent.

The statute provides that a valid patent may not be granted for an invention that has been disclosed in a printed publication more than a year prior to the filing date of the application. Publication includes other patents issued within the previous year.

This brings up an interesting and somewhat un-

13 TIPS ON KEEPING A NOTEBOOK

1. Date every entry.
2. Identify its purpose—e.g. to test the life of a diode, or the gain of an amplifier.
3. Use index pages.
4. Indicate the person working with you in connection with the material entered.
5. Be generous with sketches. This applies to equipment setups used in taking data as well as to designs and circuits. Remember that if it is vital to relate data to a particular setup five or ten years from now, you will then welcome your own diagram.
6. Label the axes of a graph and give it a title. Mark it so that later it can be recognized for what it is without depending upon memory.
7. If someone else makes an entry in your notebook, he should date and sign the entry to identify it as his.
8. Do not skip pages, planning to go back later and make entries on them. Entries should be chronological on successive pages. Never tear pages out of the notebook.
9. Cross out unused space on pages. This adds weight to the information in the notebook by precluding the possibility of a later entry being made under an earlier date.
10. If it is very necessary to add a note to a prior entry, indicate it by placing it in the margin and dating it so it can't be misconstrued as an attempt to falsify the record.
11. Consider it standard practice to insert in your notebook such items as progress reports, memos, letters, or any other pertinent material. If the added material relates to a previous entry, write a reference to it on the added sheet. Allow one unused page of the notebook for each sheet added. It is better practice not to place extra sheets on top of other entries or to add several sheets to one page. Write the corresponding notebook page number on the sheet or sheets, date it with the date it was added to the notebook and sign it.
12. Ideas should be fully described and illustrated with sketches and then explained to a suitable witness who should then make the following entry at the bottom of each explained page: Explained to me (or Read and Understood), Signature, Date.
13. Complete data for early trials should be recorded. First operation of a model which is technically known as "reduction to practice," should be demonstrated to someone who understands it and the observer should make a note near the description of data, graphs, sketches, etc., which represent the trial, as follows: Operation and Results Observed, Signature, Date.

usual situation. One inventor may claim an invention that another inventor disclosed in a patent but failed to claim. Suppose, for example, a computer manufacturer gets a patent by describing a whole computer and claiming only the general system. And suppose that he fails to claim a new magnetic drum memory used in his computer. You, let us say, have been perfecting this same memory drum for five years. Now, you can file an application for a patent on the drum. You must, however, file within a year after the issuance of his patent. And then you must prove that you had the drum working before he applied for his patent. Here again your engineering records can substantiate your proof.

Records are vital when two applications collide

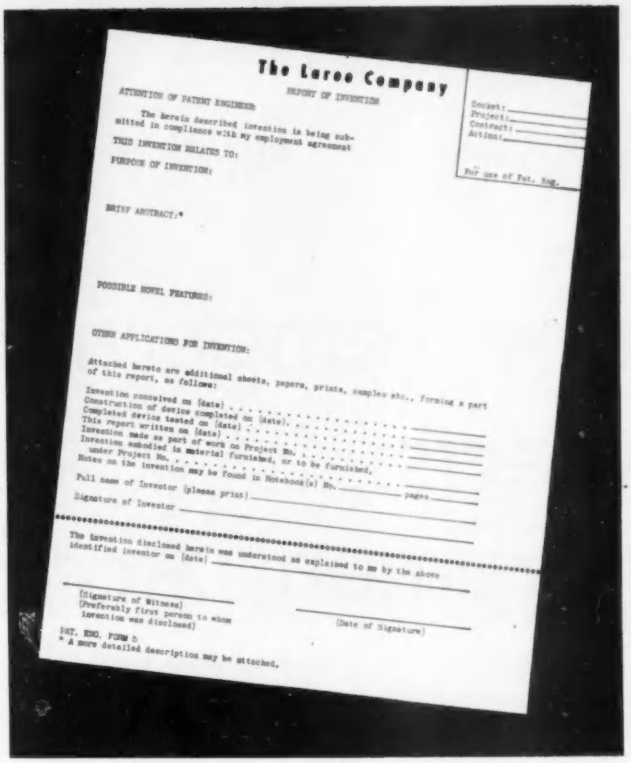
The situation would be entirely different if the computer manufacturer had claimed—as well as disclosed—the new magnetic drum. The Commissioner of Patents cannot issue two valid patents for the same invention. So, if you filed your application within a year after the computer patent was issued, he must base his decision on a procedure known as "interference." This is one of the most technical of all legal procedures. If you win the interference, you will get a patent, and the courts will hold the other fellow's patent invalid.

After his novelty search, the patent examiner looks for possible interference by going over other pending patents. If he finds an interference, it is up to the junior applicant (the latest to file) to prove the priority of his invention. Ordinarily, he has no chance unless his work predated filing by the senior applicant. Once an interference is established, as it often is when two people have the same idea at roughly the same time, both parties file sworn preliminary statements. A typical one attests to the date of the first drawing, the date of the first written description, the date of the first disclosure to others, the date of the first reduction to practice, and the date when the applicant began to reduce his invention to practice. Backed by proper records, the inventor should have no trouble helping his attorney prepare a satisfactory preliminary statement.

The first written description and drawing are fully significant only if they completely disclose a working embodiment. It is not safe to omit even those minor features that you might feel would be obvious.

The first disclosure to others is intended to mean a disclosure to a technically competent person. If the inventor states that he went home and told his wife: "I invented a new wide-band analog function multiplier today," and proceeds to describe it while she's setting the table, this will not be later accepted as a "disclosure to others," unless she happens to be a qualified electrical engineer.

An inventor's own statement that he conceived his idea on or before a certain date is held to be



The Laroe Company

REPORT OF INVENTION

Docket: ________
Project: ________
Contract: ________
Action: ________

For use of Pat. Eng.

ATTENTION OF PATENT ENGINEER:

The herein described invention is being submitted in compliance with my employment agreement

THIS INVENTION RELATES TO:

PURPOSE OF INVENTION:

BRIEF ABSTRACT:*

POSSIBLE NOVEL FEATURES:

OTHER APPLICATIONS FOR INVENTION:

Attached hereto are additional sheets, papers, prints, samples etc., forming a part of this report, as follows:

Invention conceived on (date) . . . . ________
Construction of device completed on (date). . . . . ________
Completed device tested on (date) . . . . ________
This report written on (date) . . . . ________
Invention made as part of work on Project No. . . . . ________
Invention embodied in material furnished, or to be furnished, under Project No. . . . . ________
Notes on the invention may be found in Notebook(s) No. ________ pages ________

Full name of Inventor (please print) ________

Signature of Inventor ________

The invention disclosed herein was understood as explained to me by the above identified inventor on (date) ________

(Signature of Witness)
(Preferably first person to whom invention was disclosed)

(Date of Signature)

PAT. ENG. FORM 5
* A more detailed description may be attached.

THIS FORM ENCOURAGES ENGINEERS TO GET PATENTS UNDERWAY

self-serving and not admissible as evidence. He must have a witness—not a co-inventor, whose statement would be equally self-serving. A supervisor, if he has one, would make an ideal witness.

Corroborating actual reduction to practice is not so simple as corroborating conception of an invention. Take the case of the gadgeteer who showed a potato peeler to friends in his living room. Its purpose was obvious, but because he failed to peel any potatoes for his guests, this was held not to be a reduction to practice. Take an example more pertinent to control engineering—a new stable oscillator. It's not enough to prove that the oscillator was operating without any load other than the oscilloscope hooked up to observe the wave pattern. The inventor has to put the oscillator in a piece of equipment under a working load.

The corroborating witness must be prepared to testify that the components involved in the test corresponded to those shown in the patent application. In the case of the oscillator, he should independently trace the circuit at the time of the test and see for himself that it corresponds to the one recorded in the notebook. Better yet, he should make his own written and dated record of the test.

Make it simple and you'll get more disclosures

Often, as research progresses, it becomes obvious that something patentable is evolving. At that time a record of patent conception should be prepared. It is my experience that engineers tend to neglect making disclosures rather than fill out lengthy forms. To cut down on the paperwork, I have therefore evolved the form shown at the end of this article. Its unique advantage is that it provides space for only the briefest description of the invention. Yet the room is almost always adequate for an engineer to write a succinct statement of his idea. And should any other report be available—e.g., a routine progress report or a memorandum to management—it can be attached to the form. This saves the engineer the bother of writing up a separate disclosure.

Organizations engaged primarily in research and patent licensing generally provide for elaborate patent record keeping. But in manufacturing companies, where patents are incidental to the main work, the simple procedures outlined in this article can solve both budgetary and human-resistance problems.

Knowledge emanating from research is a corporate asset worth protecting. Project supervisors should feel responsible for adequate notebooks. And management would be wise to set up controls for this phase of a company's activity. Notebooks, for instance, can be microfilmed and stored.

Engineering data filed in an engineer's head is lost the day the man moves to another company. Take a tip from the treasurer—he doesn't let the cashier carry the corporate funds in his own wallet.

How Temperature Affects Instrument Accuracy

THE GIST: Temperature changes can effect the spring constant of a resilient member, the resistance of an electrical conductor, or the magnetic properties of a permanent magnet. And since all precision instrument and control componets use these elements, the accuracy of a component depends partly on the ability of a designer to compensate for these changes in ambient temperature. He does this by using materials that are insensitive to temperature change, by combining elements that vary in an opposite manner under the same change, or by keeping the component at a constant temperature regardless of ambient variation.

As the first of a series, this article discusses the effect of temperature change on various mechanical and electrical elements. Succeeding issues of CONTROL ENGINEERING will suggest practical methods of compensating for these temperature effects and will discuss the compensating techniques used in a variety of commercially available components.

ROBERT GITLIN, Servomechanisms, Inc.

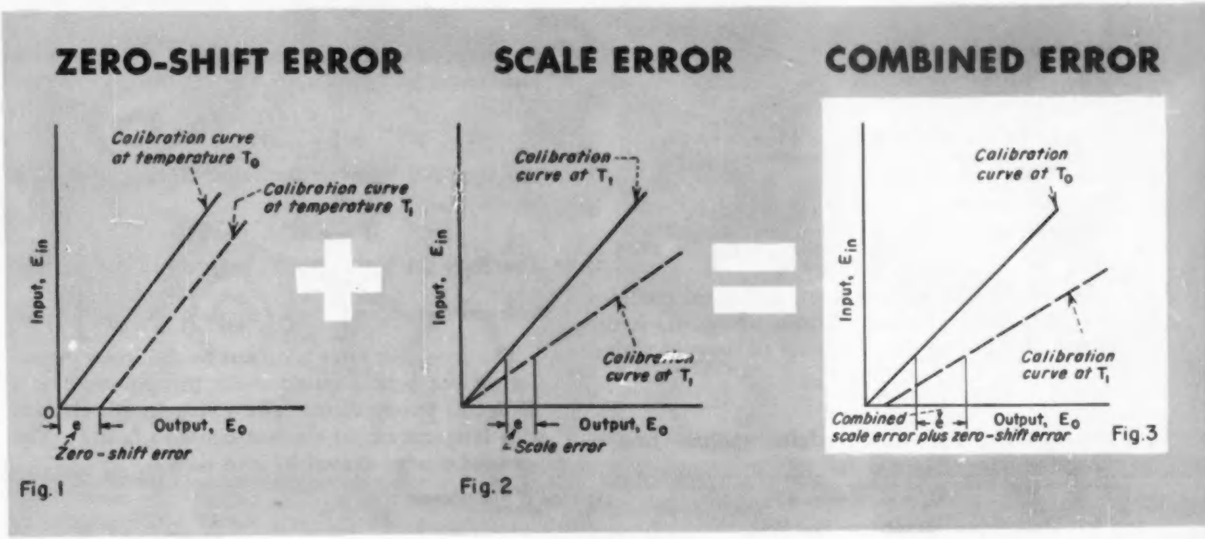
MECHANICAL SENSING ELEMENTS are used in a large class of instruments that measure force, pressure, temperature, acceleration, and velocity. These elements move as a function of the quantity being measured. This movement is then translated either mechanically or electrically into a meter movement or indication, or else into an electrical, hydraulic, pneumatic, or mechanical signal for use in a control system. When the sensing element of the instrument operates under varying ambient temperature conditions, the dimensions and physical properties of the element change. This can cause either of two major types of temperature error.

The first type is called zero shift. This is a change in the input-vs-output curve of the instrument that is typified by a shift in the calibration point at zero input. Figure 1 shows an input-output curve for a theoretical sensing element. The dotted line indicates the zero shift caused by operation at a different ambient temperature. Notice that the zero-shift error, e, is the same at all points along the calibration curve.

The second major type of temperature error is called scale error. This is caused by a change in the physical properties and dimensions of the sensing element. Scale error is characterized by a change in slope of the calibration curve, Figure 2. The error, e, increases with the input function, E_{in}.

The total temperature error is the sum of the zero shift and scale error. These effects combine to give a calibration curve as shown in Figure 3.

The zero shift shown in Figures 1 and 3 is con-



Typical input-output curve showing effect of zero-shift error. FIG. 1

Typical input-output curve showing effect of scale error. FIG. 2

Calibration curve showing both zero-shift and scale errors. FIG. 3

sidered a positive error. It is possible also to get a negative zero shift; so that for zero input the output is negative. Similarly the slope of the curve at a different ambient temperature can be greater or less than the original calibration curve at temperature T_0. Figure 4 shows how these combinations can give various new calibration curves at temperature T_1.

How zero shift and scale error affect the input-output curve of a common spring scale is shown graphically and schematically in Figure 5 (next page).

ERRORS IN RESILIENT MEMBERS

A spring deflects in proportion to the applied weight W. If ambient temperature rises substantially, then the physical dimensions of the spring increase: wire diameter, length, and coil diameter. In addition, the modulus of elasticity changes with temperature. The change in the dimensions of a material is defined by the coefficient of thermal expansion, while the change in modulus is defined by the thermoelastic coefficient.

The coefficient of thermal expansion, α, can be expressed as follows:

$$\alpha = \frac{1}{L_0}\frac{\Delta L}{\Delta T} \qquad (1)$$

where L_0 = original length
ΔL = change in length
ΔT = change in temperature

The new length of material L_1 after a change in temperature ΔT is the original length L_0 plus the change in length ΔL. $L_1 = L_0 + \Delta L$.

or substituting in Equation 1,

$$L_1 = L_0\,(1 + \alpha\,\Delta T) \qquad (2)$$

Similarly the thermoelastic coefficient of Young's

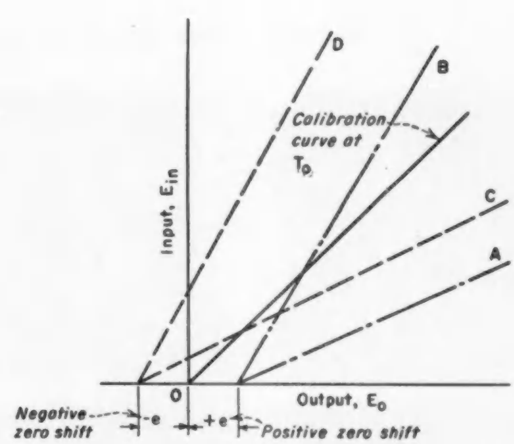


Fig. 4

A- Positive zero-shift and decreased-slope scale error
B- Positive zero-shift and increased-slope scale error
C- Negative zero-shift and decreased-slope scale error
D- Negative zero-shift and increased-slope scale error

Calibration curves resulting from various combinations of negative and positive zero-shift and scale errors. FIG. 4

modulus can be expressed

$$c = \frac{1}{E_0}\frac{\Delta E}{\Delta T} \tag{3}$$

where E_0 = modulus of elasticity or Young's modulus
ΔE = change in modulus of elasticity
ΔT = change in temperature

The new modulus of elasticity resulting from a change in temperature is

$$E_1 = E_0\,(1 + c\,\Delta T) \tag{4}$$

The thermoelastic coefficient, m, of the modulus of rigidity, G, is similarly defined where ΔG is the change in the modulus of rigidity of shear modulus.

$$m = \frac{1}{G_0}\frac{\Delta G}{\Delta T}$$

Therefore the new shear modulus resulting from a change in temperature is

$$G_1 = G_0\,(1 + m\,\Delta T) \tag{5}$$

To determine quantitatively how these changes effect the spring constant-deflection force ratio of a helical spring, insert the length and modulus for the ambient temperature T_0 in the generalized equation for this spring configuration. At temperature T_0

$$\text{Spring constant} = \frac{X}{W} = \frac{KD^3}{d^4G} = \text{slope of curve at } T_0 \tag{6}$$

where X = deflection
W = load
K = constant
D = coil diameter
d = wire diameter
G = shear modulus

At temperature T_1 the new slope of the deflection-force curve is

$$\frac{X}{W} = \frac{KD^3\,(1 + \alpha\,\Delta T)^3}{d^4(1 + \alpha\,\Delta T)^4 G(1 + m\,\Delta T)} \tag{7}$$

and the ratio between the slope at T_0 and at T_1 is

$$\frac{1}{(1 + \alpha\,\Delta T)(1 + m\,\Delta T)} \tag{8}$$

Therefore the scale error in per cent of full scale is

$$\text{Scale error, per cent} = \left[1 - \frac{1}{(1 + \alpha\,\Delta T)(1 + m\,\Delta T)}\right]100 \tag{9}$$

The zero shift error is caused by the linear expansion of the helical spring under the influence of a change in temperature. The spring length changes with temperature an amount equal to $L_0\alpha\Delta T$. The per cent change caused by zero shift is

$$\text{Per cent change} = \frac{\Delta L}{L_0}\,100 = 100\,\frac{L_0\alpha\,\Delta T}{L_0} = (\alpha\,\Delta T)100 \tag{10}$$

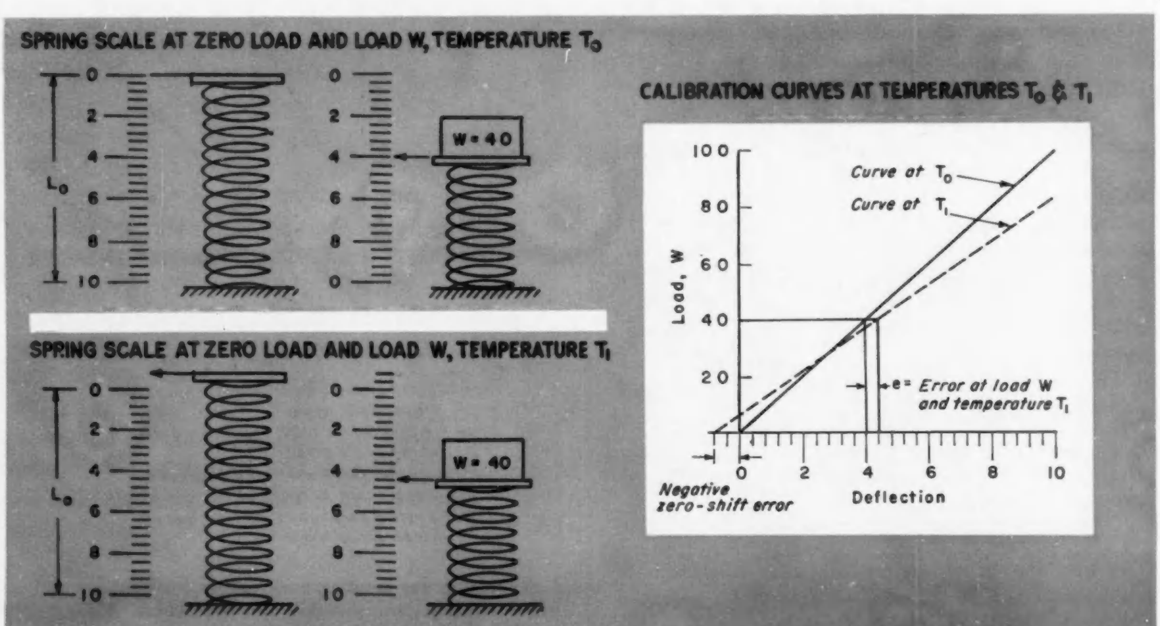
The total per cent change or error of a helical spring sensor under a change in temperature ΔT is the sum of Equations 9 and 10.

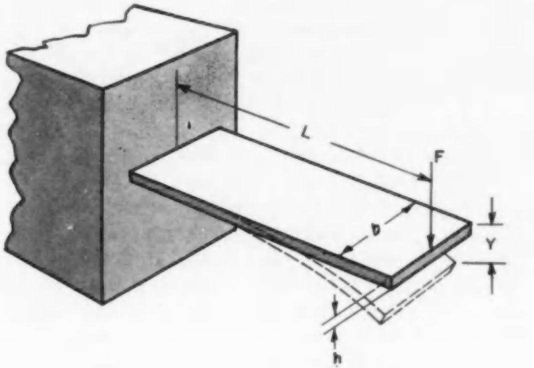
$$\text{Total error, per cent} = \left[\frac{\text{zero shift}}{\pm(\alpha\,\Delta T)} + \frac{\text{scale error}}{\left(1 - \frac{1}{(1 + \alpha\,\Delta T)(1 + m\,\Delta T)}\right)}\right]100 \tag{11}$$

OTHER SPRING CONFIGURATIONS

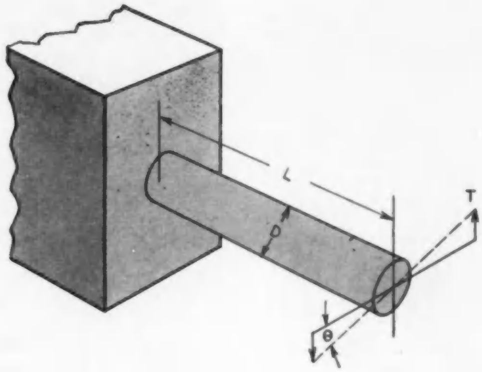
The same reasoning holds for sensing elements

Effect of various errors on a common spring scale. FIG. 5





Deflection of a cantilever spring under load. FIG. 6



Angular deflection of torsion spring by applied torque. FIG. 7

that are essentially cantilever-type springs, Figure 6. The generalized equation for the deflection per unit force is

$$\frac{Y}{F} = \frac{KL^3}{EI}$$

where F = force
Y = deflection
L = length
E = Young's modulus
I = moment of inertia of cross-section = $^1/_{12}bh^3$
K = constant

The spring constant for the cantilever type spring is

at T_0

$$\frac{Y}{F} = \frac{KL_0^3}{Ebh^3}$$

at T_1

$$\frac{Y}{F} = \frac{K[L_0(1 + \alpha\,\Delta T)]^3}{E(1 + c\,\Delta T)[b(1 + \alpha\,\Delta T)][h(1 + \alpha\,\Delta T)]^3}$$

The ratio of the above two equations is

$$\frac{1}{(1 + c\,\Delta T)(1 + \alpha\,\Delta T)} \qquad (12)$$

This is the same equation for scale error as the one derived for the helical spring sensor, except for the substitution of c, the thermoelastic coefficient of Young's modulus, for m, the thermoelastic coefficient of the modulus of rigidity. The zero-shift error is a function of the length of the spring, its geometry and the manner in which it is being used as a sensing element.

The third general type of sensor spring is a torsional member whose angular deflection is a function of some input torque, Figure 7. The generalized equation for the angular deflection per unit of applied torque for a torsional member is

$$\frac{\theta}{T} = \frac{KL}{D^4G}$$

where K = constant
L = length
D = diameter
G = shear modulus
θ = angular deflection
T = torque

The scale error is found in a similar manner

Scale error, per cent =

$$\left[1 - \frac{1}{(1 + \alpha\,\Delta T)^3(1 + m\,\Delta T)}\right]100 \qquad (13)$$

The zero-shift error is again a function of length, geometry, and the way the spring deflection drives an indicator or pickoff.

USING THESE RELATIONSHIPS

For the scale error to be zero, the term

$$\frac{1}{(1 + \alpha\,\Delta T)^3(1 + m\,\Delta T)}$$

in Equation 13 must equal one, or

$$(1 + \alpha\,\Delta T)^3(1 + m\,\Delta T) = 1$$

Expanding and discarding second-order terms, the following relation is obtained.

$$3\alpha = -m$$

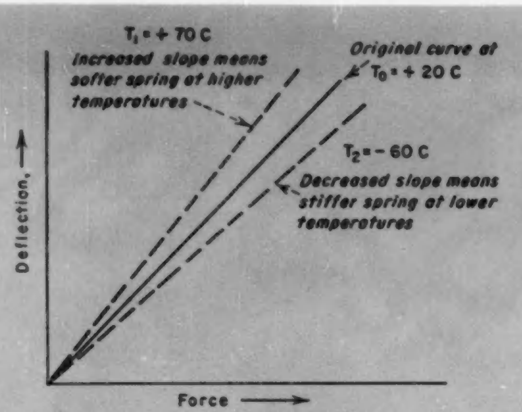
For the helical spring the relation between the coefficient of expansion and the thermoelastic coefficient is

$$\alpha = -m$$

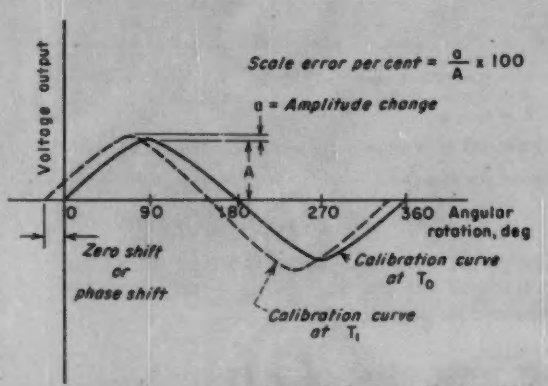
and for the cantilever spring the relation for zero-scale error is

$$\alpha = -c$$

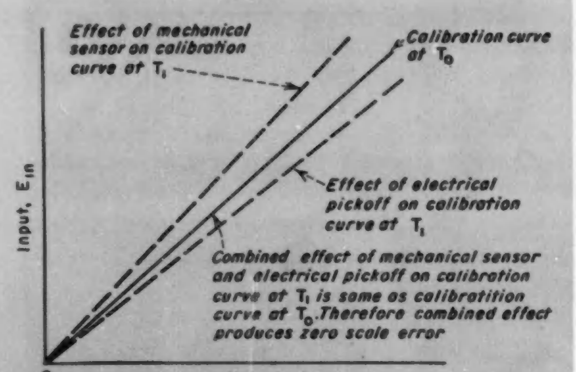
It is interesting to note that the scale error of these three commonly used springs is independent of the physical dimensions of the springs and depends only on the thermoelastic coefficient, linear expansion coefficient, and change in temperature. For example, any torsion spring made of beryllium copper



Calibration curves for a typical beryllium copper torsion spring as temperature varies from minus 60 to 70 deg C. Original calibration made at 20 deg C. FIG. 8



Temperature errors in an electrical element with sinusoidal output. FIG. 9



One way to compensate for temperature errors; balance scale error of mechanical element in one direction against scale error of electrical element in other direction. FIG. 10

will have a scale error of

$$\text{Scale error, per cent} = \left[1 - \frac{1}{(1 + \alpha\,\Delta T)^3(1 + m\,\Delta T)}\right]100$$

where $\alpha = 0.0000166$ in. per in. per deg C
$m = -0.00033$ per deg C
$T = +1$ deg C

or Scale error, per cent $= -0.028$ per deg C increase in temperature.

The minus sign in the above equation indicates that the original deflection-force ratio at T_0 is less than the deflection-force ratio at temperature T_1. Or the new deflection-force ratio has a greater slope than the original ratio. In terms of spring softness, this means that for a given force a greater deflection will occur at T_1 than at T_0. Higher temperatures mean softer springs.

If the temperature decreases, ΔT in the above equation becomes negative and m becomes positive. The result is a positive scale factor indicating that the deflection-force ratio has decreased and the spring has become stiffer. Figure 8 shows the changes in slope with temperature.

For a temperature range of minus 60 to 70 deg C, the scale error of a beryllium copper spring calibrated at 20 deg C is

$$(-80)(0.028) = -2.24 \text{ per cent}$$
$$(50)(0.028) = 1.40 \text{ per cent}$$

Without temperature compensation, the accuracy of an instrument having this spring as a sensing element could be no better than minus 2.24 to 1.4 per cent error over a temperature range of minus 60 to 70 deg C. In addition, any zero shift will add to the error (or subtract from the error) as shown in Figure 4.

Table I lists the generalized equation for the deflection-force ratio for the commonly used spring configurations and some typical spring metals and the associated scale error for each type of spring.

Table II lists a large number of available spring materials with temperature coefficients. Data on some thermoelastic coefficients is not available.

ELECTRICAL TEMPERATURE ERRORS

Many instruments produce an electrical output proportional to an input. This input could be acceleration, flow, pressure, velocity, vibration, frequency, or light intensity. A sensing element detects the measured quantity and then changes some parameter in the electrical circuitry to produce the desired variation in electrical output. The parameter that is changed can be resistance, capacitance, magnetic reluctance, or inductance—depending on the type of electrical pickoff associated with the instrument.

Physical properties of these electrical elements vary with temperature just as did the mechanical sensing devices. In highly accurate instruments, the magnitude of these changes is an important factor.

As with the mechanical elements, the principal types of temperature errors associated with electrical pickoffs are scale errors and zero shift.

The sine-wave output of an electrical pickoff device is shown in Figure 9, with the new output sine wave caused by a change in temperature indicated by the dotted curve. The difference between these two curves is the temperature error. Changes in the amplitude of the output wave are scale errors, while changes in phase correspond to zero-shift errors.

If the electrical output is a linear function of the input, then a curve similar to Figure 4 can be plotted to show the effect of temperature on the input-output ratio.

In determining the overall temperature error of an electromechanical transducer, it is necessary to take into account all of the errors associated with the sensing element. One method of overall compensation consists of matching the negative error associated with the movement of a mechanical spring with the positive scale error associated with changes in resistance. Figure 10 indicates how these errors could be combined to produce zero scale error.

Table III, which lists the temperature-sensitive properties of wire materials, helps calculate the changes in resistance and hence the scale error associated with many electrical pickoffs. This error can then be matched with a mechanical sensing element having an equal and opposite scale error. The equations for scale error given in this article, together with Tables I and II, provide data to calculate a large variety of resilient sensing elements.

It is necessary also to investigate the effect of zero shift, which may or may not cancel. If a zero shift error remains, some appropriate form of temperature compensation must be used.

TABLE I

Scale Errors for Various Materials and Spring Configurations

Spring configuration	*Generalized equation for deflection-force ratio*	*Material*	*Scale error per deg C in per cent (minus 50 to 50 C)*
		Music wire	0.025
		Stainless steel (302)	0.042
HELICAL	$\frac{X}{W}=\frac{KD^3}{d^4G}$	Phosphor bronze	0.038
		Beryllium copper	0.031
		Monel	0.031
		Ni-Span-C	0.0008
		Music wire	0.026
		Stainless steel (302)	0.041
CANTILEVER	$\frac{Y}{F}=\frac{KL^3}{EI}$	Phosphor bronze	0.034
		Beryllium copper	0.032
		Monel	0.029
		Ni-Span-C	0.0008
		Music wire	0.022
		Stainless steel (302)	0.039
TORSIONAL	$\frac{\theta}{T}=\frac{KL}{D^4G}$	Phosphor bronze	0.035
		Beryllium copper	0.028
		Monel	0.028
		Ni-Span-C	0.002

TABLE II TEMPERATURE CHARACTERISTICS OF SPRING MATERIALS

	Material	Composition, per cent		Young's modulus or modulus of elasticity, lbs per sq in.	Modulus of rigidity or shear modulus, lbs per sq in.	Coefficient of linear expansion, in. per in. per deg C x 10^6 (0 to 100 C)	Thermoelastic coefficient of Young's modulus, per deg C x 10^5 (−50 to 50 C)	Thermoelastic coefficient of modulus of rigidity, per deg C x 10^5 (−50 to 50 C)	Applications
FLAT COLD ROLLED SPRING STEEL	Watch spring steel	Carbon Mn	1.10–1.19 0.15–0.25	32,000,000	Not Used	14.4			Mainsprings for watches, etc.
	Clock spring steel	Carbon Mn	0.90–1.05 0.30–0.50	30,000,000	Not Used	11.5	−21	−20	Clock and motor springs.
	Flat spring steel	Carbon Mn	0.65–0.80 0.50–0.90	30,000,000	Not Used	11.8	−24	−24	Miscellaneous flat springs.
CARBON STEEL WIRES	High carbon wire	Carbon Mn	0.85–0.95 0.25–0.60	30,000,000	11,500,000	11.5	−21	−20	High grade helical springs.
	Oil tempered wire, ASTM A229-41	Carbon Mn	0.60–0.70 0.60–0.90	29,000,000	11,500,000	11.8	−25	−28	General spring use.
	Music wire, ASTM A228-41	Carbon Mn	0.70–1.00 0.30–0.60	30,000,000	11,500,000 to 12,000,000	11.7	−27	−26	Miscellaneous small high quality springs.
HOT ROLLED SPRING STEEL	Hot rolled bars	Carbon Mn	0.90–1.05 0.25–0.50	28,500,000	10,500,000	11.5	−21	−20	Heavy coil or flat springs.
ALLOY AND STAINLESS SPRING MATERIALS	Chrome vanadium alloy steel, SAE 6150	Carbon Mn Chrome Vanadium	0.45–0.55 0.50–0.80 0.80–1.10 0.15–0.18	30,000,000	11,500,000	12.3	−26	−26	
	18-8 type stainless steel, Type 302	Chrome Nickel Carbon Mn Si	17– 20 7– 10 0.08–0.15 2 Maximum 0.30–0.75	28,000,000	10,000,000	16.8	−43	−44	Best corrosion resistance. Fair temperature resistance.
	Spring brass	Copper Zinc	64– 72 Remainder	15,000,000	5,500,000	20.1	−39	−39	High electrical conductivity at low and stresses. For corrosion resistance.
	Nickel silver	Copper Zinc Nickel	56 25 18	16,000,000	5,500,000	16.2	−35	−37	Better quality than brass. Corrosion resistant.

NON-FERROUS SPRING MATERIALS	Phosphor bronze	Copper	91— 93	15,000,000	6,250,000	17.8	−36	−40	Used for corrosion resistance and electric conductivity.
		Tin	7— 9						
		or Copper	94— 96						
		Tin	4— 6						
	Monel	Nickel	64	26,000,000	9,500,000	14	−30	−32	Resists corrosion, moderate stresses to 400 F.
		Copper	26						
		Mn	2.5						
		Iron	2.25						
	Inconel	Nickel	80	31,000,000	11,000,000	11.5			Resists corrosion. High stresses to 650 F.
		Chrome	14						
		Iron	Balance						
	Z-Nickel	Nickel	98	30,000,000	11,000,000	13			Resists corrosion. High stresses to 550 F.
		Copper							
		Mn	Small						
		Fe	Amounts						
		Si							
	Beryllium copper	Copper	98	16,000,000 to 18,500,000	6,000,000 to 7,000,000	16.6	−35	−33	High fatigue life, low hysteresis, good electrical conductivity.
		Beryllium	2						
LOW-COEFFICIENT ALLOYS	Invar	Nickel	36	21,400,000	8,100,000	1.08	+4.8		Minimum thermal expansion.
		Fe	Balance						
	Modulvar	Nickel	34.9	21,000,000	8,000,000	0	+4.8		Similar to Invar.
		Fe	64.5						
		Carbon	0.16						
		Mn	0.18						
		Cr	0.12						
		Si	0.14						
CONSTANT-MODULUS ALLOYS	Elinvar	Nickel	33-35	21,500,000	8,300,000	0.6	−0.66	−0.72	Used in hairsprings and balance wheels, tuning forks for radio synchronization. Practically non magnetic.
		Cr	4- 5						
		Si	0.5- 2						
		Tungsten	1- 3						
		Mn	0.5- 2						
		Fe	61-53						
		Carbon	0.5- 2						
	Isoelastic	Nickel	36	26,000,000	9,200,000	7.2	−3.6 to +2.7		Used for spring scales, precision measuring instruments.
		Cr	8						
		Mn	0.5						
		Fe	Balance						
	Ni-Span-C	Nickel	42	24,000,000 to 27,000,000	10,000,000	8.1	−1.0 to +1.0		Constant modulus high strength.
		Cr	5.5						
		Ti	2.5						
		Al	0.4						
		Carbon	0.06						
		Mn	0.4						

TABLE III — TEMPERATURE CHARACTERISTICS OF ELECTRICAL CONDUCTORS

	Material	Composition, per cent	Nominal specific resistance Ohms per cm-ft at 20 C	Resistance Temp. coef. per deg C	Resistance Temp. range deg C	Linear Expansion Temp. coef. per deg C	Linear Expansion Temp. range deg C	Remarks
ALLOYS	Tropet A	Ni 80, Cr 20	650	0.00011	20 to 500	0.000017	10 to 1000	High temp. resistors.
	Nichrome V							
	Tropet C	Ni 60, Cr 15	675	0.00015	20 to 500	0.000017	20 to 1000	High temperature resistance elements.
	Nichrome	Ni 60, Cr 16						
	Evanohm	Ni 75, Cr 20	800	±0.00002	—50 to 105	0.000010	20 to 100	Precision resistors.
	Karma	Ni 73, Cr 20						
	Cupron	Ni 45, Cu 55	294	±0.00002	20 to 100	0.0000149	20 to 100	Thermocouple wire (Constantan).
	Advance	Ni 43, Cu 57						
	Manganin	Mn 13, Balance Cu	290	±0.000015	15 to 35	0.000008	25 to 425	Precision resistors for bridge and decade boxes.
	Manganin shunt strip		230	±0.000015	40 to 60			Shunt for dc ammeters.
	180 Alloy	Ni 22, Cu 78	180	0.00018	—50 to 150	0.0000175	20 to 500	
	Midohm	Ni 23, Cu 77						
	90 Alloy	Ni 12, Cu 88	90	0.00049	—50 to 150	0.0000175	20 to 500	
	95 Alloy	Ni 11, Cu 89						
	60 Alloy	Ni 6, Cu 94	60	0.0008	—50 to 150	0.000018	20 to 500	
	Lohm							
	Ballo	Ni 70, Fe 30	120	0.0042	20 to 100	0.000015	20-1,000	Used in ballast tubes.
	Hytemco	Ni 72, Fe 28						
PURE METALS	Platinum		63.8	0.0030	20 to 100	0.0000089	20 to 100	
	Iron		60.14	0.0050	20 to 100	0.0000117	20 to 100	
	Molybdenum		34.27	0.0033	20 to 100	0.000005	20 to 100	
	Tungsten		33.22	0.0045	20 to 100	0.000004	20 to 100	
	Aluminum		16.06	0.00446	20 to 100	0.000024	20 to 100	
	Gold		14.55	0.0034	20 to 100	0.0000142	20 to 100	
	Copper		10.37	0.00393	20 to 100	0.0000166	20 to 100	
	Silver		9.796	0.0038	20 to 100	0.0000189	20 to 100	

IDEAS AT WORK

C-G Control Copes With Shifting Fuel

R. L. BERGESON
Aeronautical Div.,
Minneapolis-Honeywell Regulator Co.

A pilot can focus on the manual scheduling of fuel to maintain the proper relationship and optimum trim for flight. But the many other functions demanding his attention make the need for an effective automatic-center-of-gravity control system apparent.

An autopilot system does not escape the same problem. To prevent overstresses during extreme maneuvers, an autopilot's output must be limited by a torque restrictor. If c-g is allowed to vary widely, this torque must be held to minimum to prevent damage. The result is sluggish control. Precise c-g control, however, permits higher torque restrictor setting and maximum performance by the autopilot at all times.

In the typical application discussed here, the required relationship of forward tank to aft tank fuel for any total fuel quantity is shown in Figure 1.

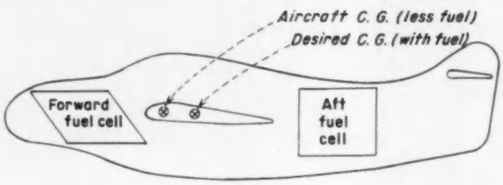
$$w_2d_2 = w_3d_3 \quad (1)$$

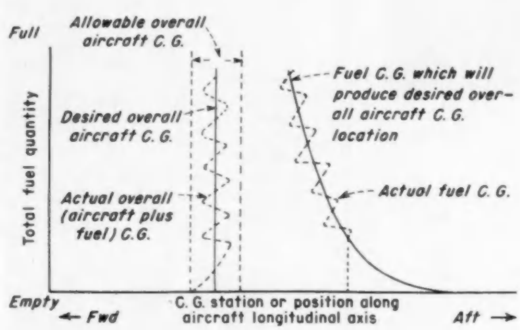
and

$$W_1d_1 = (w_3 + w_2)\, d_4 \quad (2)$$

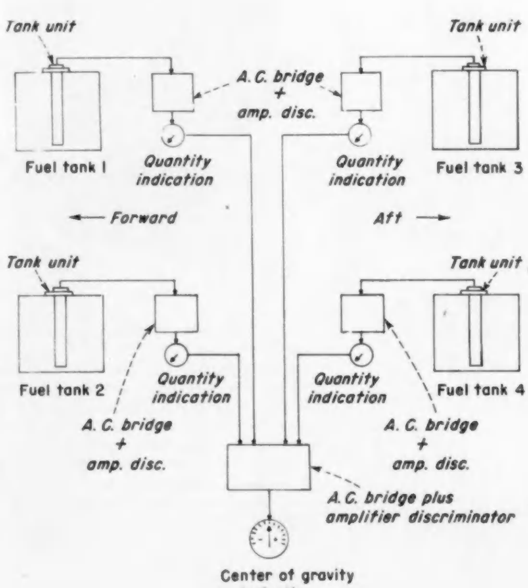
where w_1, w_2, w_3 are measured in pounds and d_1 d_2 d_3 d_4 in inches.

The problem is essentially one of controlling the operation of pumps or valves to maintain the desired moment





THE PROBLEM: More than half the gross weight of a loaded aircraft is fuel. Its distribution at any given instant has a pronounced effect on the overall center-of-gravity. Yet c-g must always be held within certain limits for stable, controlled flight. The control problem illustrated is typical. With both fuel tanks full the relative c-g's of aircraft-less-fuel and fuel-tanks cause overall c-g to fall at the desired location. But as fuel is used and total mass decreases, the combined fuel c-g must move away from the desired position if the airframe is to stay in balance.



THE SOLUTION: The only way to solve the problem is by controlling distribution of fuel in the various tanks. The block diagram shows a system that frees the pilot from this complex task. Capacitance sensors, patterned to tank shape, provide signals proportional to fuel moment. A bridge circuit compares fuel moments on either side of the balance point. And the output signal is used to control fuel management devices as well as to assure the pilot visually that the load is indeed balanced.

balance ($M_1 = M_2$) about the desired fuel c-g. This can be done with capacitance-type sensing elements in each tank along with an ac bridge circuit, controller, and control relay.

Fuel-Sensing Element

The sensing element is a cylindrical electrostatic capacitor mounted vertically in the aircraft fuel tanks. It consists of two concentric tubes spaced and insulated from each other. The inner electrode is made of an insulating material. Two metallic patterns, insulated from each other, are attached to this latter surface. One of these, the sensing pattern, is connected to an appropriate terminal to form one active plate. The other electrode is an aluminum tube, the second active plate of the capacitor.

There is a well-defined relationship between the dielectric properties of an aircraft fuel and its density. Thus the sensing element mentioned above will have a certain capacitance when in air (usually about 100 to 500 mmf, depending on length), which approximately doubles when completely immersed in fuel.

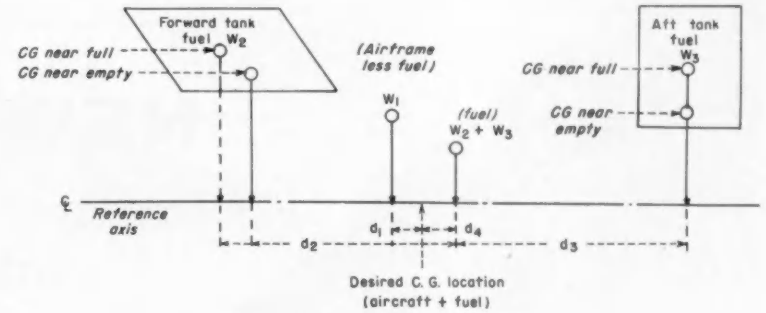
For each specific tank design, the inner electrode conducting pattern is characterized by varying its area to give an output capacitance proportional to fuel moment. In the conventional sensing element there is no regard for the fuel moment arm.

As shown in Figure 2, voltage E_1 is applied to capacitance C_1 and voltage E_2 to C_2. Hence when fuel moment balance exists, the system is adjusted to make $E_1 C_1 = E_2 C_2$, and therefore $E_3 = 0$.

The bridge output is amplified and applied to a phase-sensitive discriminator tube with a control relay in its output. Since bridge balance, corresponding to moment balance, produces zero output, it follows that a slight unbalance—aft tank heavy, for instance—will produce an output voltage with polarity determined by the direction of unbalance. In this example, if the aft fuel moment exceeds the forward moment, the bridge output energizes the control relay and calls for draining the heavy tank.

Figure 3 (next page) describes the basic c-g bridge circuit.

When using a step type of control, like a relay, moments are not kept in exact balance but permitted to deviate from side to side in amounts dictated by the allowable c-g limits of the aircraft. Therefore a specified limit



Fuel-airframe c-g relationship. FIG. 1

of moment unbalance, M, must be sensed, rather than an exact balance.

$$M = M_2 - M_3 \qquad (3)$$

$$M = w_2 d_2 - w_3 d_3 \qquad (4)$$

where M is the moment unbalance or sum of the moments about the desired fuel c-g location.

The capacitance sensing units must be characterized so that the added capacitance due to the fuel at any level in the tank is proportional to the corresponding moment as expressed in equations (5) – (8):

$$C_1' \approx M_1 \qquad (5)$$

$$C_2' \approx M_2 \qquad (6)$$

$$K_1 C_1' = M_1 \qquad (7)$$

$$K_2 C_2' = M_2 \qquad (8)$$

Where C_1' and C_2' are the added capacitances, with fuel as a dielectric of the sensing units in Tanks 1 and 2 respectively.

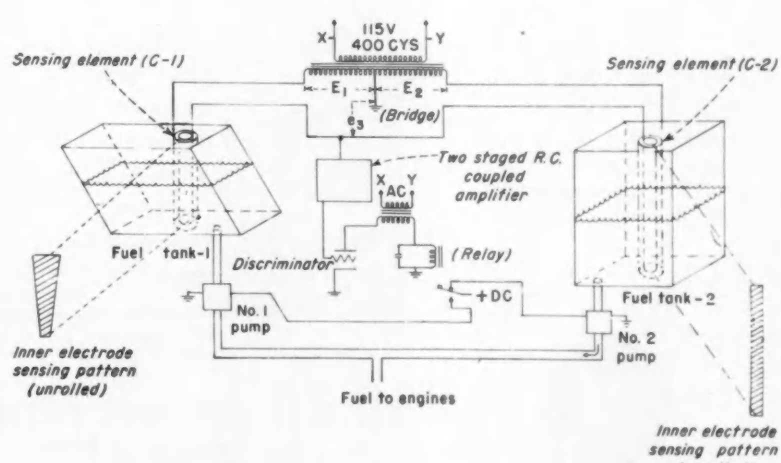
K_1 and K_2 are constants of proportionality relating fuel moment to added capacitance of the sensing units and are read in lb-ft per mmf. Substituting (7) and (8) in (3), the expression of moment unbalance in terms of sensing unit capacitances becomes:

$$M = K_1 C_1' - K_2 C_2' \qquad (9)$$

The bridge circuit in Figure 4 will provide a means of summing the moments electrically and of measuring any resulting unbalance. The bridge output voltage or unbalance signal e_3 can be expressed by:

$$e_3 = \frac{E_1 (C_1 - C_1') - E_2 (C_2 + C_2')}{C_1 + C_1' + C + C_2' + C_3} \qquad (10)$$

where C_1 is empty or dry capacitance of the sensing unit in Tank 1.
C_2 is empty or dry capacitance of the sensing unit in Tank 2.
C_3 is capacitance in shunt with bridge output terminals.
e_3 is the bridge output or unbalance signal.
E_1 is the ac voltage impressed on C_1 and C_1'.
E_2 is an ac voltage 180 deg out of phase with E_1 and impressed upon C_2 and C_2'.



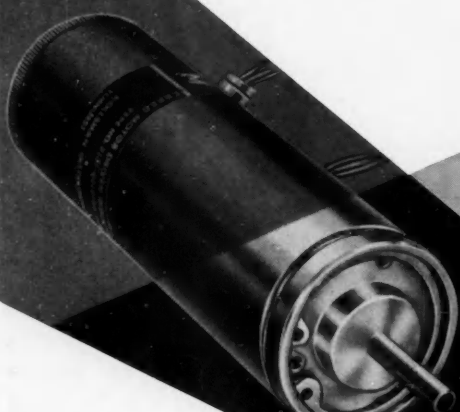
Elements of the control system. FIG. 2

COMMON CHARACTERISTICS OF ALL TYPE 2131 GEARED MOTOR GENERATOR UNITS

O.D. of Case............1.000 inch
Case Length............3.301
Weight............7.5 ounces
Frequency............400 cycles

No. of Poles (Motor)............6
*No Load Speed (Min.)............6500 rpm
Rotor Inertia............1.1 gram-cm²

*Motor Speed at input to gear train



NEW
integral gear head in small servo motors

OUTSTANDING FEATURES OF TYPE 2131 GEARED MOTOR GENERATOR

- New methods of manufacture result in high efficiency
- High torque to inertia ratio to give fast response
- Available for 115 volt—115 volt two phase or single ended tube operation
- High impedance winding for direct plate to plate operation available
- High generator output voltage with excellent signal to noise ratio
- Zero degree phase shift in generator
- All metal parts corrosion resistant
- Extremely wide operating temperature range

Other models of one inch O.D. units

TYPE NO.	DESCRIPTION
2103	Induction Motor
2101	Geared Induction Motor
2028	Motor Generator

A new line of units has been added to the Kollsman "Special Purpose Motors" family combining precision machining, advanced electrical design and the latest in new materials. An unusual feature of the new line is the integral gear head unit. Contained within a single case is the gear train and motor; or gear train, motor and generator. Gear ratios as high as 300:1 can be supplied.

This new line consists of Induction Motors and Induction Generators supplied separately or combined in a single case one-inch in diameter. The new motors have been designed to give the maximum torque per watt ratio with the minimum rotor inertia. The generators have been designed to give the maximum output voltage with the minimum residual voltage and phase shift.

One of the principal features of the Kollsman "Special Purpose Motors" is the interchangeability of parts which permits numerous electrically different combinations of motor and generator windings within the same case.

INPUT PER PHASE ONLY 1.8 WATTS

ELECTRICAL CHARACTERISTICS OF TYPICAL TYPE 2131 GEARED MOTOR GENERATORS

Latest catalog and/or complete specification drawings will be sent upon request.

	MOTOR					GENERATOR		
TYPE NO.	EXCITATION FIXED	EXCITATION CONTROL	INPUT PER PHASE	STALL TORQUE	Theoretical Acceleration At Stall	EXCI-TATION FIXED	INPUT	OUTPUT PER 1000 rpm
2131-0411110	26	26	2.3	0.4	25600	26	1.8	.51
2131D-0412120	26	26	4.0	0.6	38500	26	2.2	.68
2131D-0413120	26	26	1.8	0.3	19200	26	2.2	.68
2131-0460600	115	115	4.0	0.6	38500	115	2.6	1.00
2131-0463600	115	55	4.0	0.6	38500	115	2.6	1.00
2131-0470600	115	P-P	4.0	0.6	38500	115	2.6	1.00
	volts	volts	watts	Oz-n	rad/sec²	volts	watts	volts

kollsman INSTRUMENT CORPORATION

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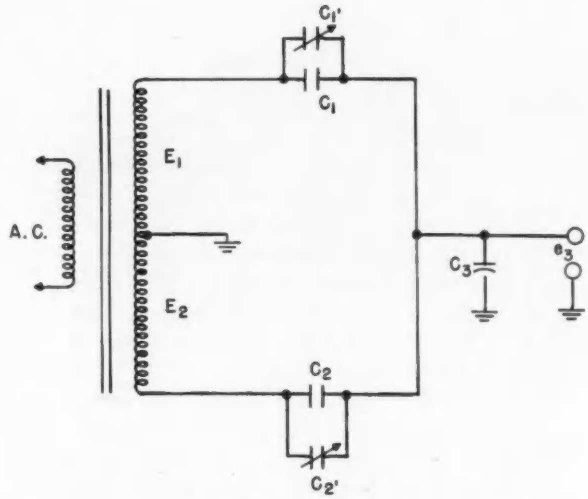
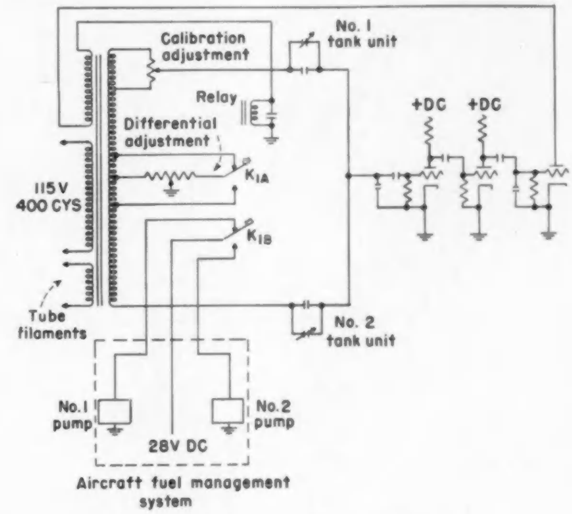


Basic c-g control bridge circuit. FIG. 3



Schematic of the control system. FIG. 4

Equation (10) may be rearranged:

$$e_3 = \frac{E_1C_1' - E_2C_2'}{C_1+C_1'+C_2+C_2'+C_3} + \frac{E_1C_1 - E_2C_2}{C_1+C_1'+C_2+C_2'+C_3} \quad (11)$$

$$\text{or } e_3 = K_3C_1' - K_4C_2' + K_5 \quad (12)$$

$$\text{where } K_3 = \frac{E_1}{C_1+C_1'+C_2+C_2'+C_3} \quad (13)$$

$$K_4 = \frac{E_2}{C_1+C_1'+C_2+C_2'+C_3} \quad (14)$$

$$K_5 = \frac{E_1\ C_1 - E_2C_2}{C_1+C_1'+C_2+C_2'+C_3} \quad (15)$$

and K_3, K_4 and K_5 are nearly independence of fuel level if $(C_1 + C_2 + C_3) = (C_1' + C_2')$.

Comparing equations (9) and (12), it is evident that if K_5 in (12) were equal to zero, the equations would be similar and the voltage e_3 would then be proportional to the moment unbalance M. To eliminate K_5, $E_1\ C_1$ must be equal to $E_2\ C_2$, which is equivalent to having the bridge balanced when the fuel tanks are empty. Rewriting (12) under these equalifying conditions,

$$e_3 = K_3C_1' - K_4C_2' \quad (16)$$

e_3 and M are related by a constant of proportionality K_6.

$$M = K_6e_3 = K_6K_3C_1' - K_6K_4C_2' \quad (17)$$

Equating coefficients of equations (17) and (9)

$$K_1 = K_6K_3, \text{ and } K_2 = K_6K_4 \quad (18)$$

$$\text{or } K_6 = K_1/K_3 = K_2/K_4 \quad (19)$$

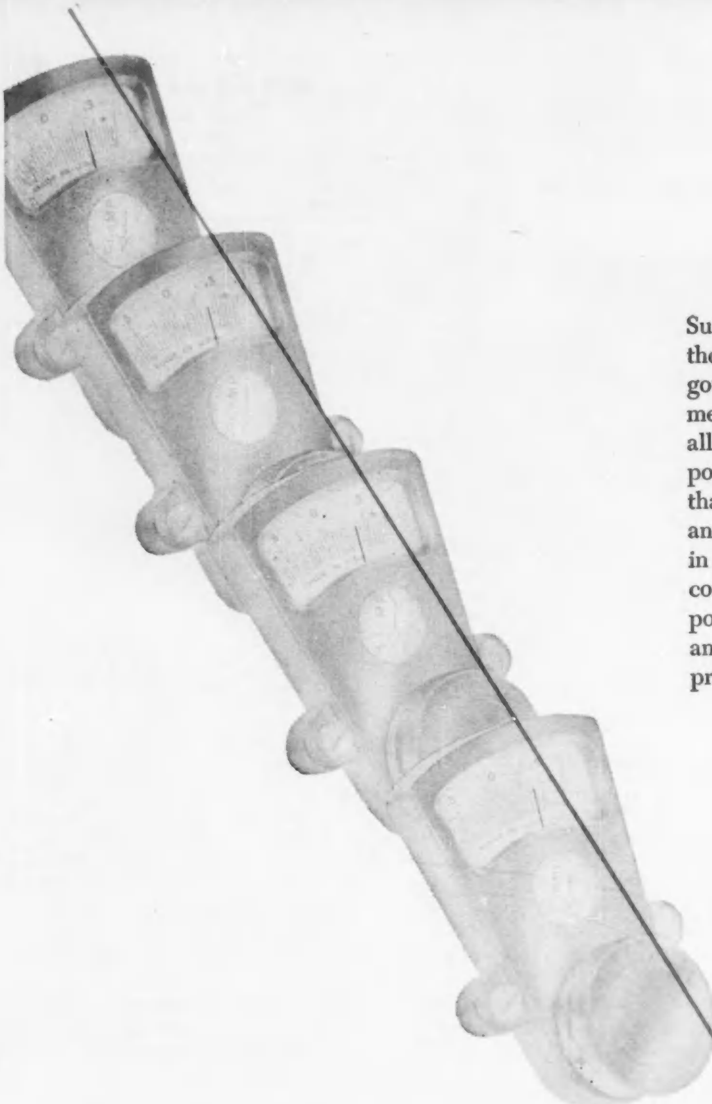
$$\text{and } K_1E_2 = K_2E_1 \quad (20)$$

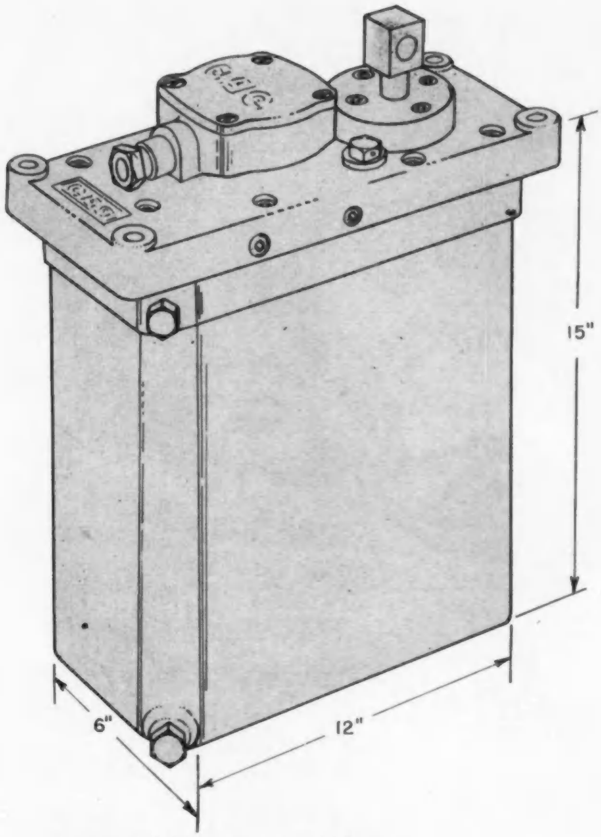
where K_6 a constant relating bridge unbalance to moment unbalance.

DIFFERENTIAL CIRCUIT

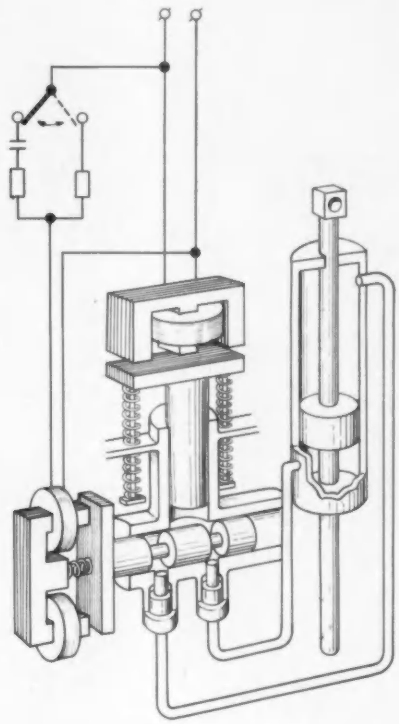
The actual bridge circuit in Figure 4 incorporates a novel and very important feature. Analysis of the circuit will show that when contact is broken on either side of contacts K_{1A}, an additional voltage will be introduced into the bridge to reinforce the action which originally opened the contact. This will cause the armature to close on the opposite contact with a pronounced "snap action." This action provides positive relay operation under conditions of shock, vibration, and fuel sloshing.

In addition, this differential adjustment offers a precise means of regulating the amount of fuel unbalance that will occur on either side of the nominal path determined by the tank unit pattern design. This is important because it permits ready establishment of deviation limits that are an acceptable compromise between the number of valve or pump operations per flight and the tolerable range of aircraft c-g location.





The sealed hydraulic system displays a cable box and actuator head. FIG. 1



Inside the box: the pump, valve, and cylinder. The switch and capacitor can be put anywhere. FIG. 2

Tiny Hydraulic System Acts Like Super Two-Way Solenoid

This actuator combines the fast starting and positive stopping of hydraulic systems with the simple hookup and unit independence of electrical gear. It should be applicable to valve operation, machine-tool motion, and transfer machine propulsion.

It develops lineal motion by first converting current to hydraulic pressure through a small pump and then controlling this pressure with a valve that operates on phasic relationships. A hydraulic cylinder finally changes this controlled flow to motion. This may seem a roundabout way of doing the job, but the "Hydromagnet" works well and costs little.

The Hydromagnet has two electromagnets with associated movable armatures. As the gap between magnet and armature can be kept rather small, the efficiency of the device is fairly high. The upper electromagnet is the power source. Its armature oscillates with the 60-cycle 110-or-220-volt source. This armature is attached to a pump piston. The valve for this pump is operated by the other electromagnet. This electromagnet is the control element. A capacitor in its circuit causes it to oscillate the valve "out of phase" with the pump piston so as to divert the flow of hydraulic fluid to lift the actuator piston, or without the capacitor, to oscillate in a phase that will lower the actuator piston. As a result, speeds of up to 2 in. per sec with a 44 lb load are achieved. When the control circuit is open, the actuator is locked.

The Hydromagnet weighs 72 lb filled. Made by AEG, Frankfort/Main, West Germany, its distributor in the US is D. C. Seibert, Box 281, Wilmington, Del.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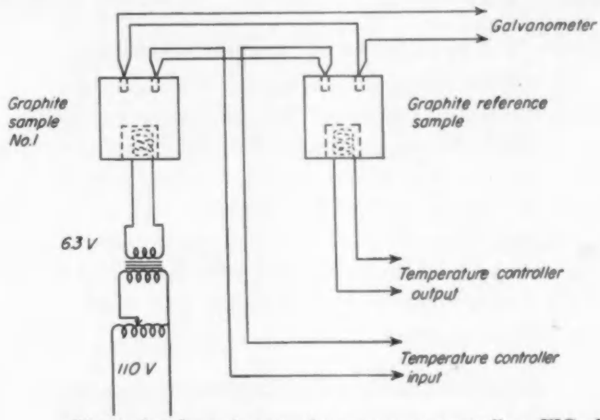
Stress-Energy Measurement Needs Fast Temperature Follower

G. L. SMITH,
Atomic Energy Div., Phillips Petroleum Co.

This system measures energy stored in crystals by physical stress—for example, by cold working. It follows the conversion of stress to heat, using two servos to get proportional temperature control. One servo follows microvolt differences in the input from two thermocouples. The other controls a heat source by this error and its first derivative in time.



Circuit for dynamic test of temperature controller. FIG. 1

Energy stored in crystalline materials by physical stress—cold working, for example—can be measured. Usually, a stressed sample and a reference sample, identical in all other respects, are placed in an evacuated vessel whose wall temperature is raised linearly with time. If the temperature rise is slow the sample and reference materials will each receive thermal radiation from the walls and undergo a linear rise in temperature also. When a critical temperature is reached, the energy stored in the stressed sample becomes available to raise its temperature above the reference material.

Both the specific heat and thermal conductivity of most materials are functions of temperature. Thus, simple measurement of the temperature excursions of irradiated samples does not give a quantitative measure of the amount of stored energy released.

It is better to heat the samples separately, and to supply an amount of energy to the reference sample exactly equal to the stored energy released at each instant by the stressed sample.

In practice, the rates of release of energy may be so great that a simple on-off controller will not control the heat input well enough.

The solution is a proportional controller whose heat output is a function of the sum of the temperature difference between the samples and the time derivative of this signal.

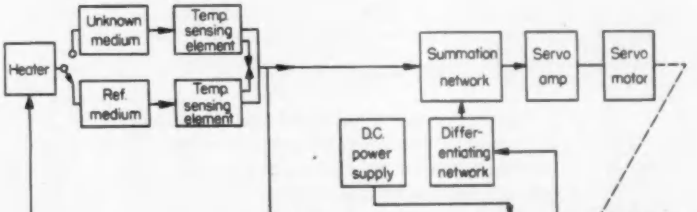
To follow a rapidly fluctuating signal without hunting, the controller must predict what demands are to be put upon it, and thus start its corrective action enough in advance so that it does not lag or overshoot the sample more than a predetermined amount. The first time-derivative of the signal provides this leading signal.

The temperature controller in Figures 2 and 3 can be divided into two major components: a differentiating network and an output network. The RC differentiating network is preceded by a servo amplifier, balancing motor (one at top in Figure 3), and a 10,000-ohm, 10-turn, helical potentiometer. The input is designed to handle signals between 2 and 50 microvolts. Signals greater than a few microvolts cause the motor to drive the pot arm.

The output of the potentiometer has the same polarity as the input but is much bigger. This voltage is impressed across the RC circuit to give the time derivative of the input signal. Currents proportional to the time derivative and the input signal are added in the 1-ohm resistor, which is common to both circuits and also gives appropriate gain adjustment. This is the signal for the output network.

The output network uses a servo to drive a variable transformer. The voltage output is a function of the signal to the network and the voltage available to the motor-driven transformer, which is supplied from a manually-set variable transformer.

The output transformer is driven through a magnetic clutch, and R_1 is



System diagram of proportional temperature controller designed for stored-stress-energy measurement. FIG. 2

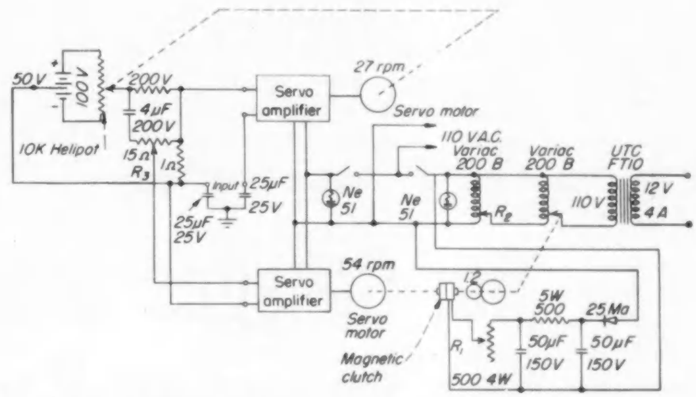
set so the clutch will slip when the transformer reaches its limits. R_2 is set so that the maximum output power available is approximately equal to the maximum demand of the system. R_3 controls the response time by determining the amount of derivative signal fed to the summing resistor.

The system response was tested as shown in Figure 1. Two 5-ohm coil heaters were inserted in 3/16-in holes bored in the bottom of small graphite cylinders. Two sets of differential thermocouples also were inserted in the blocks. One set of thermocouples was connected to the input of the controller, the other set, to a galvanometer. The galvanometer was used to monitor the differential temperature between the samples.

When 14 watts was instantaneously applied to sample number 1, the controller supplied heat to the reference sample at a rate such that the differential was never greater than plus or minus 0.5 deg C. When power to the heater was shut off instantly, at a time when power was being applied to the reference, the temperature overshoot of the reference was 0.5 deg. C.

The controller has been used also to maintain a constant bath temperature over long periods of time. With thermistors in a bridge circuit as the temperature sensing element, the maximum deviation from the reference temperature was plus or minus 0.002 deg C.

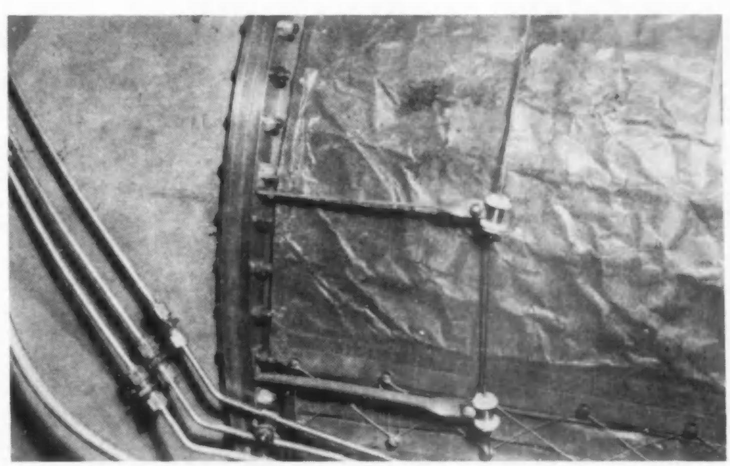
Condensed from United States Atomic Energy Commission Report No. IDO-16137, describing work performed under Contract No. AT(11)-205.



Complete circuit diagram of proportional temperature controller. Magnetic clutch protects motor if servo drives to Variac limits. FIG. 3

Flame Detector Pays No Heed to Heat

R. E. CARBAUH,
American Machine & Foundry Co.



All widely used existing fire detection systems operate on either a rate-of-temperature-rise or on fixed temperature. Although their indication of overheat is valuable, their inability to distinguish flame from severe overheat may lead to a FIRE indication where none exists. The AMF system, operating on the electrical characteristics of the flame itself, provides only FIRE or FIRE-OUT indications, almost instantaneously, while thermal systems embody substantial time lags.

The AMF system consists of a "transmitter," "receiver," and a sensing element that can be any conductor separated from the ground by insulators. An ac signal of very low harmonic content is passed through the sensing element to the receiver. The receiver is tuned to the second harmonic component of the signal which appears only when flame bridges the sensing element and ground. Suitable amplification of this second harmonic operates the warning light. Accidental grounding and sensing element operates a different warning light, and a check of the entire system is provided by a "Press-to-test" button.

The sensing element shown in the photograph is a 1/16 inch diameter stainless steel aircraft control cable riding on aluminum oxide insulators. This material withstands temperatures up to 2,000 deg F. The sensing element operates at a few volts, to reduce possibility of accidently shocking maintenance men. And since the transmitter is a high impedance source, this low voltage also reduces the chance of fire through accidental grounding.

Present sensing systems also suffer from the possibility of lead-in wires to the sensing element being burned and accidentally grounding, giving an indication of fire after it is out. By using the same steel wire as its own lead-in, AMF avoids that difficulty. CAA is now testing the new system.

FINANCIAL AID TO HIGHER EDUCATION

Our Colleges and Universities Are Living on Borrowed Time

. . . time borrowed from underpaid faculty members

The chart on this page tells a story of profound importance to every American. It is the story of the financial beating our college and university faculty members have been taking in the past 14 war and postwar years.

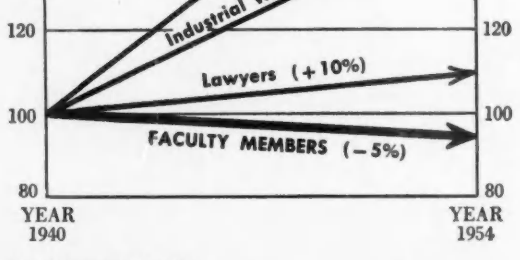
On the whole, this span of 14 years has been one of great and growing prosperity. But, as the chart shows, our college and university faculty members have, as a group, had less than no share in it.

During this period, from 1940 through 1954, the real income of the average industrial worker (that is, what his wages would purchase in goods and services) has increased by almost one-half. Among professional groups, physicians have enjoyed an increase of about 80 per cent in their real income. Lawyers, far less favored financially, have had an increase of about 10 per cent. But faculty members have not only had no increase at all; over these years of prosperity their average real income has fallen by 5 per cent. These figures do not take account of the increase in taxes since 1940.

Senior Teachers Hardest Hit

These figures are, of course, averages. For some groups of faculty members it has been better; for others worse. It has been particularly hard on senior faculty members. Between 1941 and 1953 their salaries lost about 8 per cent of their purchasing power. Being deeply committed to their careers they could not respond to alternative employment opportunities as readily as could their junior colleagues. For junior faculty members there was some increase in real income between 1941 and 1953 but only about half as much as the average for the nation.

What's Happened to College Faculty Salaries*



* Real Income before Taxes.

Source: Council for Financial Aid to Education: U. S. Dep't of Commerce: U. S. Dep't of Labor.

Public Colleges Fare Better

There are also marked differences in the average financial reward received by faculty members in different types of colleges and universities. A recent study by the Council for Financial Aid to Education indicates that, in the last academic year, 1953-1954, teachers in privately endowed, independent colleges and universities were paid an average salary about $1000 less than that paid to faculty members in tax-supported institutions. The same study indicates that salaries far below the average are especially common for faculty members in the small private liberal arts colleges. This study found that during the last academic year the average salary of all college and university faculty members was about $4700.

The special difficulties under which the independent colleges and universities, and particularly the independent liberal arts colleges, are laboring to get back on their feet financially have been discussed in previous editorials in this series. These difficulties underline the need of special help for these institutions to which business firms are now contributing in increasing volume. However, the problem of providing better salaries is not peculiar to any particular type of institution.

Faculty Members Not Greedy

It is not easy to prescribe a precise standard of fair pay for college and university faculty members. This is partly because they put less weight relatively on money rewards than they put on rewards of scholarly accomplishment and prestige. Consequently, they have consistently been willirg to work for very modest salaries in relation to the intellectual ability, education and application required. Obviously, however, it is the dictate both of fairness and good judgment to see that faculty members are given a roughly proportionate share in the general prosperity. Indeed, their crucial role in our society could be made to justify a larger share than this.

There is no way to know with any degree of precision what the underpayment of our college and university faculty members over the past 14 years has actually cost the nation in terms of reduced quality of intellectual performance of those institutions. One reason is that the damage has been minimized by the devoted services of many faculty members who have loyally stuck to their jobs in spite of the great financial discouragement.

It is obvious, however, that, if no grave deterioration in the intellectual performance of our colleges and universities has occurred so far, it is because we have been living on borrowed time. It is time borrowed from faculty members who have, in effect, been subsidizing these institutions by their financial sacrifice. This arrangement is not only a menace to the cultural and intellectual life of the nation, it is also a menace to our national security in a time when successful national survival may well depend in peculiar degree on the full development and utilization of our intellectual resources. We depend on our college and university faculties pre-eminently to provide this development. Adequate financial reward for such service is an elementary form of national insurance.

Many of our colleges and universities are working hard to improve the financial lot of their faculty members. Business firms are also playing an increasing role of providing the necessary financial assistance. The methods being used by business for this purpose will be the subject of another editorial in this series. However, **vastly more must be done, and quickly, to stop the financial beating being taken by our college and university faculty members if the nation's welfare and safety are to be properly protected.**

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Donald C McGraw

PRESIDENT

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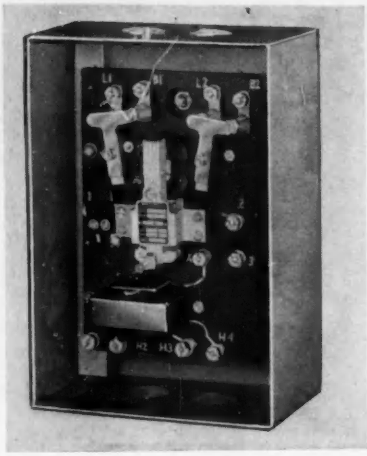
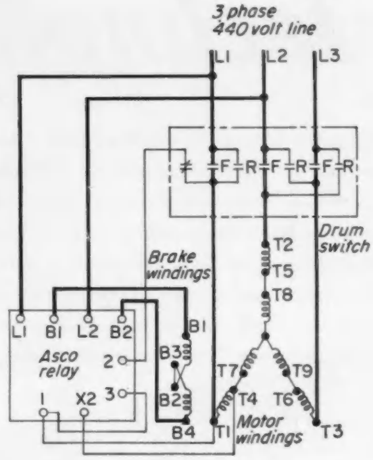
NEW PRODUCTS

LISTING IN GROUPS





VERSATILE T-D RELAY adapts to any standard ac, copes with meter loads directly.

In control engineering the humble relay is taken for granted like the corner cop. And, like the cop, it's called upon for many tasks. It can switch, amplify, diminish, divert, store. In groups relays can do unbelievably complex jobs. It is truly a rallying point for all law-abiding control systems.

The time-delay relay illustrated above has been dressed up to increase its utility for rough industrial use. It comes in a dust-proof NEMA cabinet. Its delay mechanism can be screw-driver adjusted from ½ to 6 sec. And it's tapped transformer sets it up for all standard ac voltages (120, 240, 460, 600 v, 60 cycles).

One important virtue of this relay is its ability to handle a motor load without a separate dc source. The wiring diagram shows how its done. In this case a brake winding is superimposed upon the stator winding of a standard squirrel cage motor. Thus, each time the meter-drum switch is operated to the stop position, the relay closes and energizes the brake winding. The brake is then deenergized ½ to 6 sec. later, according to relay setting. Similar connections permit an across-the-line motor starter control.

This versatile relay also can be used in "single-pulse" time-delay applications. Each momentary push-button action causes the relay to close and connect the line of the controlled equipment. The circuit is then disconnected after the selected time delay. Repeat cycling action also is possible. *Automatic Switch Co., 391 Lakeside Ave., Orange, N. J.*

Circle No. 1 on reply card

HOW TO SELECT A RELAY

Automatic Switch Company has industrial applications mainly in mind when it lists these three conditions for evaluating a relay:

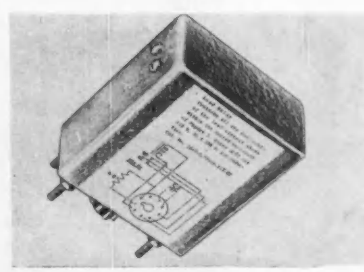
1—The maximum current the relay will be required to "make" against.

2—The maximum current the relay must carry continuously.

3—The maximum current the relay must break.

This information plus some well documented relay selection charts and control circuit diagrams are all to be had on a single sheet from the company. Write for ASCO Publication No. 553.

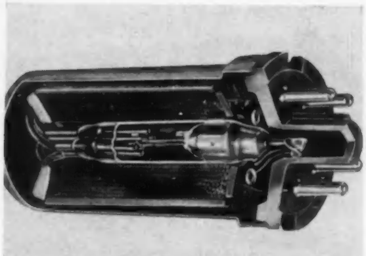
MORE RELAYS FOR THE CONTROL ENGINEER



PLUG-IN makes relay meter-compatable.

This relay is one of a line specifically designed for a plug-in use as contral elements in meters. It is actually a load relay containing a 5 ma relay. 200 mfd timing condenser, and limiting resistor. Action of the unit is this: it pulls in at 5 ma, releases at 1.5; its condensor, connected across the coil, gives a 5 sec delay on release. All connections in this 4-by-5-in. unit are brought out to a nine-pin octal-type plug. *Assembly Products Inc., Chesterland, Ohio.*

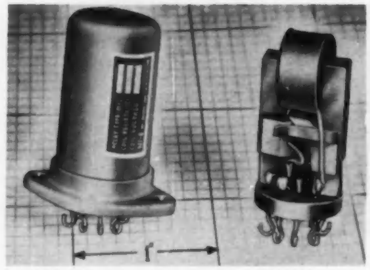
Circle No. 2 on reply card



MERCURY-WETTED contacts perform long and fast.

The platinum contact surfaces in this relay are kept continuously wet with mercury by capillary action. Further, the switch itself is encapsuled in glass and under hydrogen pressure. These qualities give the relay exceptionally long life and ability to operate at very high speed. They have performed a billion operations, at up to 60 per sec, with no maintenance. Current carrying capacity is up to 5 amp, voltage handling capacity to 500 v. Operation uniformity is claimed within 1.5 millisec. *C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Ill.*

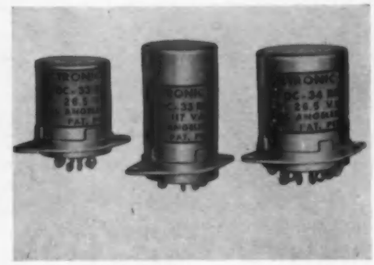
Circle No. 3 on reply card



THIMBLE SIZED, more bounce to the ounce.

It weighs 1 oz and is only $1\frac{1}{2}$ in. high. Yet this two-pole relay is claimed to withstand shock accelerations in excess of 20 G's at frequencies up to 2,000 cps with no contact break. It will also operate up to 200 deg C and its insulation resistance is greater than 100 megohms. Some characteristics: contact current rated at 3 amp, 28 vdc, and 3 amp, 115 vac; contact resistance as low as 0.01 ohms; coil resistance 325 ohms at 28 vdc. Relays may be hermetically sealed and nitrogen filled. *Hi-G Inc., Bradley Field, Windsor Locks, Conn.*

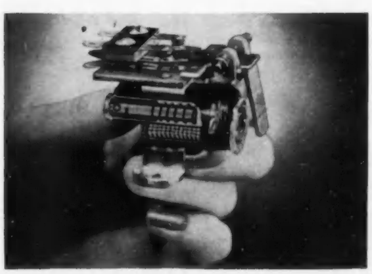
Circle No. 4 on reply card



TINY TRIO snap true when going's tough.

All three of these relays offer "snap-action" switch contacts, and are evacuated and sealed with gas to innure them to severe shock, vibration, and temperature. The one on the right, however, is toughest. It will operate true during vibration of 30G to 500 cps, or 15G to 2,000 cps and at shock of over 100 g for 11 millisec. The center unit is for ac operation, with a coil rated at 117vac. All contacts are DPDT and offered in pure silver with resistive load ratings of 2 amp at 28 vdc. *Deltronic Corp., 1507 Riverside Drive, Los Angeles 31, Calif.*

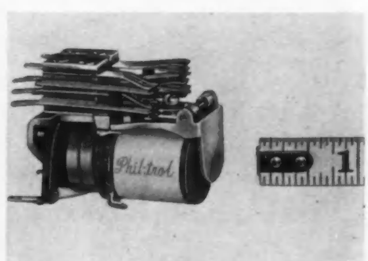
Circle No. 5 on reply card



SILICON CONTROLS this time-delay relay.

Silicon fluid, acting as a drag, can provide a selected time delay of from $\frac{1}{4}$ to 120 sec in this relay. Here's how it works. When the coil is energized a movable iron core, swimming in silicon inside a tube, is drawn inside the magnetic field. The silicon slows the rate of core travel and thus controls response time. Contact is established when the core touches the pole piece. The action offers a highly definitive contact. *Heineman Electric Co., 387 Plum Street, Trenton 2, N. J.*

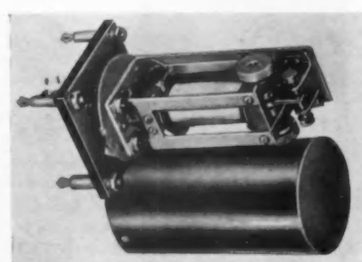
Circle No. 6 on reply card



BUILT-IN RECTIFIER trims wire and space.

Adjacent to the coil of this diminutive relay is an integral rectifier. Its use has eliminated external wiring—only standard coil terminals are required for hookup. One section of the rectifier is for half-wave control, while the other section shunts the coil to prevent ac vibration. Some characteristics: power—0.022 amp at 130v and 20 deg C; contacts—up to 4 Form C (four-pole double-throw); ambient temp. −55 deg C and 85 deg C max. limited to 2 Form C. *Phillips Control Corp., Joiliet, Ill.*

Circle No. 7 on reply card



REED ARMATURE suits this to chattery chores.

A reed-type permalloy armature with anti-chatter contacts endows this polarizing relay, we are told, with an ability to stand up under the high-pressure demands of teletypewriting. The contacts are actually extra heavy ($\frac{3}{32}$ in diam) palladium copper and the contact screws have $\frac{1}{16}$ in diam tungsten contacts, rated at 2 amp, 110 vdc. Two windings—136 ohms each—make up the coil of this relay. *Kurman Electric Co. Inc., 35-18 37th St., Long Island City, N. Y.*

Circle No. 8 on reply card

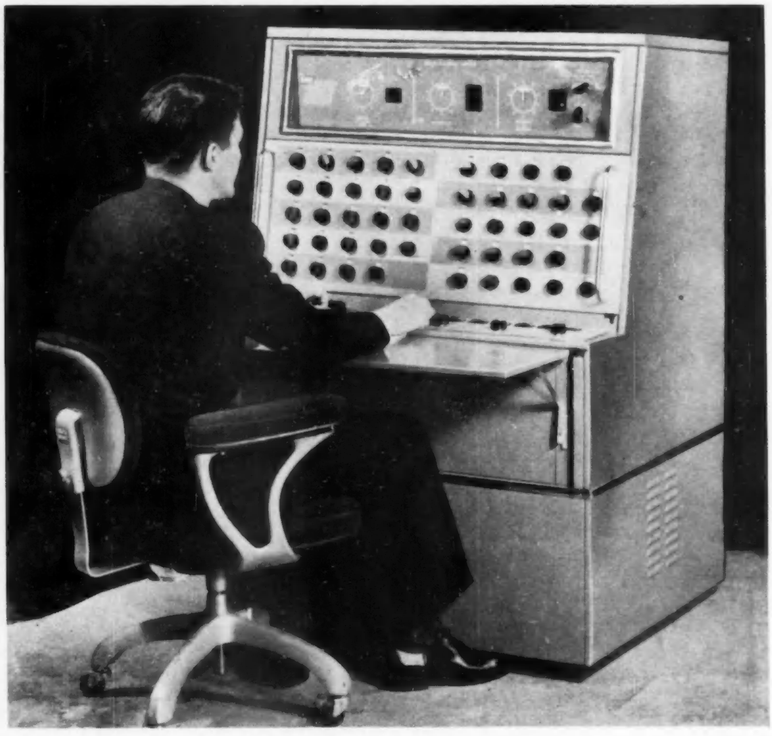
NEW PRODUCTS

AIR RELAY juggles with great dexterity.

Like its electrical counterpart, the pneumatic relay can do many jobs. Some functions it can perform: air-volume amplifying; pressure reversing, retarding, and averaging; differential controlling; minimum-pressure controlling. The unit shown is set up to "average" the air input from two or three signals sources and provide a resolved air output to a single controlled device. It is set to pass 7 psi when all input pressures are 7 psi. *The Powers Regulator Co., Skokie, Ill.*

Circle No. 9 on reply card

DIGITAL ADVANCES



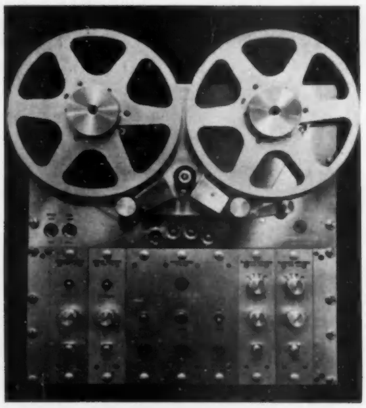
COMPUTER for simple and specialized operation.

Here's something that looks like more than a good product—it looks like a good idea as well. The selling point behind this analog computer is that it is operated by the aeronautical engineer who has the problem, and not by a specialist permanently attached to the device. Putting the whole machine on casters allows it to be rolled around an engineering office to the group who needs it.

Inputs, which are set to four significant figures, include: Mach number, pressure ratio, engine thrust, gross weight, reference area, profile drag coefficient. And the output will be

maximum speeds at steady rates of climb, lift coefficients, and climb angle. Its accuracy is said to be generally within 0.1 per cent of full scale. *Link Avition, Inc., Binghamton, N. Y.*

Circle No. 10 on reply card



TAPE RECORDER features building block assembly.

The A-V Type 7 Magnetic Tape Recorder will accept inputs from 100 to 100,000 cps. Designed around a "building block" scheme, the equipment consists of nine basic units: tape transport, head assembly, record amplifier, etc., and thirteen accessories, such as remote control panel and portable case. A new drive system helps reduce flutter well below 0.1 per cent. Four-speed drive from 7½ to 60 in. per sec tape widths up to 1 in, and one to fourteen tracks increase its versatility. *Field Engineering Division, 100 Indiana Ave., N. W., Washington 1, D. C.*

Circle No. 11 on reply card

INTERVALS timed with power-line frequency.

Power line 60 cycle is doubled to 120 cycles and fed into the counting circuit of this interval timer. When the preset recycle point has been reached, recycle to zero is automatic, and a different recycle point is set up. Thus, precise intervals, accurate to

1/120 sec, up to $8\frac{2}{3}$ sec are possible. Also available are longer counting intervals with up to four different interval lengths. *Electronic Products Div., Post Machinery Co., Beverly 11, Mass.*

Circle No. 12 on reply card

MINIATURE COUNTER has print-out for panel mounts

About the size of a portable typewriter, Streeter-Amet's print-out counter will deliver a strip of paper full of $\frac{3}{16}$ in. high numerals indicating its count, at a maximum rate of 1,000 per min. Automatic resetting at an established figure is a standard feature. Goes to 99,999 on each count. *Streeter-Amet Co., 4101 Ravenswood Ave., Chicago 13, Ill.*

Circle No. 13 on reply card

TELEMETERING oscillator converts inductance to frequency.

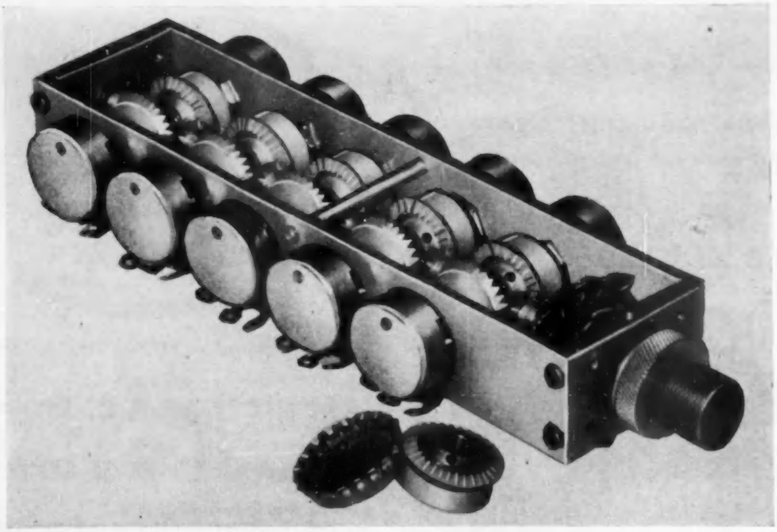
Telemetering signals from a variable-inductance pickup is facilitated by this FM oscillator. Inductance variations of the pickup modify the frequency of this oscillator from center frequencies ranging from 1 kc to 100 kc. Its built-in cathode-follower amplifier meets isolation and matching requirements of low-impedance loads. Its heater supply is 6.3 v at 600 ma or 12.6 v at 300 ma. Plate voltage is 150 vdc at 5 ma or 108 vdc at 6 ma. The oscillator was designed primarily to complement the makers P-100 pressure transducer. *Datran Engineering Corp., 6312 W. 92nd St., Los Angeles 45, Calif.*

Circle No. 14 on reply card

FEEDBACK FACT

Posed: An infallible, automatic way to assure Ma's best recipes.
Solved: Help wifey with a Magnecord tape-controlled unit which will measure, combine and mix the proper ingredients.

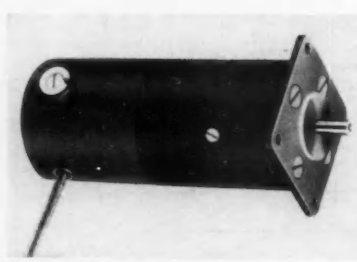
MOTION, MOTORS AND MECHANISMS



CLUTCHES in miniature sizes do a good turn.

Although they weigh only 2 oz, these tiny clutches have torques ranging up to 15 oz in. Three models, two for continuous rotation, the other for single-turn drives, can be used with input speeds of up to 200 rpm. The assembly shown above has two knobs turning ten potentiometers. One knob cuts in each clutch separately by means of a rotary switch, and the other then positions the potentiometer being driven through the active clutch. Operating at voltages from 6 to 30 dc, they draw about 1 watt. Complete engineering data on these miniature clutches called the 500 series, is available in an 8-page brochure. *Electronic Manufacturing Engineering Co., 2410 Beacon Ave., Seattle 44, Wash.*

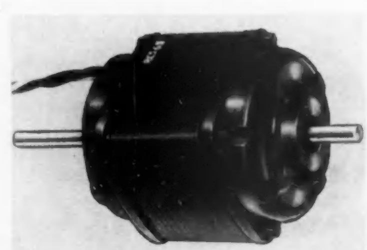
Circle No. 15 on reply card



MOTORS with a series of built-in gear trains.

Featuring gear train ratios from 3:1 to 10,500:1, these compact, light assemblies, only 1½ in. in diameter, can deliver up to 1,600 lb in. The maker takes pride in high precision throughout the manufacture of these type 3094 motor-gear trains. *John Oster Mfg. Co., Avionic Div., 1 Main St., Racine, Wis.*

Circle No. 16 on reply card



UPRIGHT MOUNTING for motor aimed at recorders.

Model RCS-65 is a permanent split-capacitor-type motor with 2 9/19 in. diam. It comes with a small cooling fan. It will deliver 4 oz-in. at approximately 1,650 rpm. Magnetic leakage has been held down to allow its application in tape recorders, where it can be mounted vertically. *Holtzer-Cabot Motor Div., National Pneumatic Co., Inc., 125 Amory St., Boston 19, Mass.*

Circle No. 17 on reply card

400 CPS MOTOR for tape recorders or servo systems.

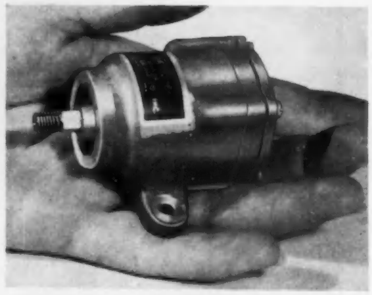
Although the standard design of this motor features it as an induction motor, it can be had as a synchronous motor with a reduced power output. The single-phase winding operates on 110 vac and turns at 11,800 rpm. Maximum power input is 45 watts, output 15 watts. The manufacturer recommends it for actuator or tape recorder use. *The Delmotor Co., 1381 Clay St., Santa Clara, Calif.*

Circle No. 18 on reply card

ROTARY transformer for angular pickups.

Although resembling a pot, this is a rotary differential transformer intended for generating position signals of control surfaces, valves, etc. Its output voltage varies linearily with angular position. A cam-shaped ferromagnetic core varies the coupling between primary and two halves of its secondary. Primary excitation is 3 to 5 at about 400 cps to 8 kc. Its sensitivity is 0.004 v per deg of rotation with a 2,000 cps exciting current at 5 v. Error is 1 per cent up to 40 deg and 3 per cent thereafter. *Schaevitz Engineering, Camden 1, N. J.*

Circle No. 19 on reply card



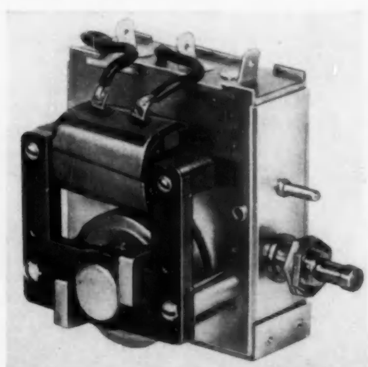
DAMPS ADJUSTABLY with little friction.

Adjustable damping, from 0.5 to 25 in.-lb per radian per sec is the feature of this mechanism. The shaft rotates 90 deg. The effect of temperature is minimized by a silicone damping fluid, which is relatively insensitive to temperature variations. *Haines Gauge Co., Inc., Bridgeport, Pa.*

Characteristics

Friction	7 oz-in.
Weight	9 oz. filled
Maximum torque	15 lb-ft

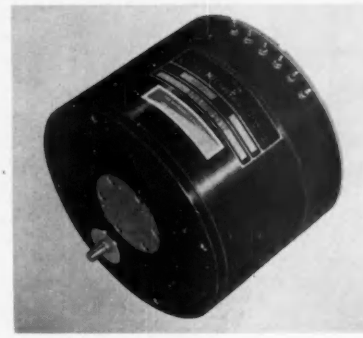
Circle No. 20 on reply card



RUGGED AND COMPACT is this PB fixed timer.

This non-adjustable timer is smaller than a citizen-sized pack of cigarettes, but it has king-sized capabilities. It has a heavy duty switch, solderless snapon terminals, and a completely enclosed switch and gear mechanism. Its fixed timing period is available from 20 sec to 24 hr. It operates on ac, 110 or 220 v, 25, 50, or 60 cycles with a 300 amp rating. The pushbutton that starts its cycle has solid silver contacts. *Miller-Harris Instrument Co., 601 East Ogden Ave., Milwaukee, Wis.*

Circle No. 21 on reply card



COSINES by a twist of the shaft.

Dual cosine output from two electrically-isolated potentiometers, plus or minus 75 deg with an accurary of 0.04 per cent should be of interest to a computer doing trig. Windings up to 200,000 ohms are available. Called Model #35,000, it weighs 4.2 lb and is about 5 in long and 5 in diam. *Gyromechanisms, Inc., Halesite, Long Island, N. Y.*

Circle No. 22 on reply card

ACCELEROMETER excels at adjustable damping.

An air-damped spring-mass system

FEEDBACK FANCY

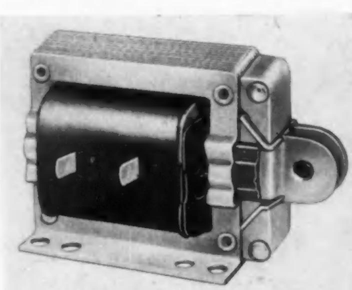
Needed: For those who invent—"automated" patenting.

Suggested: Surely the thundering horde of digital patents passing through the Department have suggested a way to beat the tedious search and weary wait? Simply a digital coding system for patents and claims, served by a central data processing facility.

has damping adjustable between 0.1 and 1.0 critical in this accelerometer. Pressure sealed, it will take up to 20 g. The resistance windings, from 5,000 to 1,000 ohms, perform with 0.25 per cent resolution and linearity of plus or minus 0.5 per cent. *Bourns Laboratories, 6135 Magnolia Ave., Riverside, Calif.* **Circle No. 23 on reply card**

PICKUP on speed control provides meter reading.

The Speed-Trol variable-speed drive can now be supplied with a tachometer generator and meter making possible direct indication in rpm or other units at ft per min. The speed reducers are available in ranges of ½ to 30 hp. *Sterling Electric Motors, Inc., 5401 Telegraph Rd., Los Angeles 22, Calif.* **Circle No. 24 on reply card**



SOLENOID pulls high in close quarters.

While the small size of this solenoid especially adapts it for compact equipment and components, its maker claims it has a very high seated pull because of its double shading coil. The unit will operate in any position and under constant or intermittent duty at 115v, 60c. Its blade terminals are standard, with flexible leads optional. *Dormeyer Industries, Dept. CLN, 3418 N. Milwaukee Ave., Chicago 41, Ill.*
Circle No. 25 on reply card

NEW PRODUCTS

INSTRUMENTS EVOLVING

METER READS both log and linear.

A unique logarithmic meter movement in this ac vacuum tube voltmeter gives the user log voltage indication and linear db readings. Thus meter reading accuracy is independent of pointer position.

Characteristics

Meter Ranges—
Volts Full Scale
0.001 to 100 by factors of 10
(cal. RMS value)
0.03 to 300 by factors of 10
DB Ranges
minus 60 to 50 in steps 10 db
Freq. Range. . . . . .20 cps to 2 mc
Error. . 3 per cent to 100kc, 5 per cent to 2 mc at any point on the

Shasta Div., Beckman Instruments, Inc., Richmond, Calif.

MV CONTROLLER for stacking in relay racks.

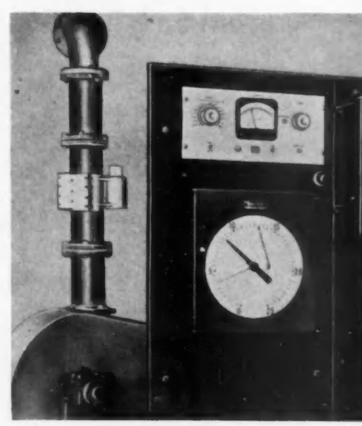
Honeywell now has a redesigned version of its millivoltmeter controller in a horizontal steel case, 19 in. wide, 6 in. high, and 10¾ in. deep. This makes it possible to stack several of the 26 lb instruments in a standard relay rack. Control modes and instrument performance are a kin to the conventional unit. *Industrial Division, Minneapolis-Honeywell Reg. Co., Wayne & Roberts, Phila. 44, Pa.*

Circle No. 26 on reply card

WEIGHT-GAGES SOLIDS or liquids in slurries passing continuously through pipes.

Wrapped around the pipeline to the left of the instrument panel is a practical example of radioactive measurement at work. It's a beam source that routes through the pipe-contained moving slurry, and an oppositely placed cell that gages the amount of absorption—and thus the percentage of solids or liquids in the slurry by actual weight. On the panel is the intermediate amplifier and the weight-percentage indicating recorder and, if desired, controller. This installation is measuring the solids content of an asbestos cement-water slurry. Similar ones are being used for slurries of clay, magnetite, grinding compounds, and coal.

The precision of this type of measurement is apparently excellent. In a 10 in. pipe length of 2.0 SpG slurry, measurements in the range of 0-40 per cent solids can be made to within 0.3 per cent solids. As the solids content increases, the maker notes precision also increases. *The Ohmart Corp., P. O. Box 67, Cincinnati 22, Ohio*

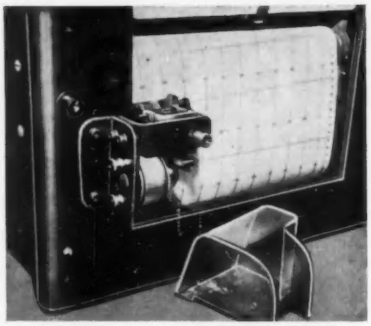


Circle No. 27 on reply card

FEEDBACK FACT

Posed: Some way of calling Dr. Kildare without waking all his patients too.

Solved: The good Doctor can now be equipped with a Radio Receptor Co. pocket job which whispers a personal beckon.



CLIPS ON to add function to stripchart record.

This device neatly clips onto the door of a strip chart recorder and will print a number, date, or time on the chart whenever it is voltage-actuated during operations. Hence, any particular happening or condition can be integrated into the chart record. It operates on 28 vdc, but can be adapted to other electrical requirements. A plexiglas cover is part of the kit and will preserve the integrity of the instrument glass. *Royson Engineering, Hatboro, Pa.*

Circle No. 28 on reply card

MODEST CONTROLLER has magnificent uses.

While the maker's price tag on this electric contact controller is low, the jobs it can tackle may involve big dollar savings. For example, its ability to act (SPDT) on small current or voltage changes suggests it actuate a machine tool re-indexing machanism (a dull tool pulls more load), set off a pH alarm, operate battery chargers, signal dangerous gas or loss of vacuum. Signal input to the unit's galvanometer-relay combination may be in microamps or millivolts, ac or dc. Control sensitivity may range from 0.2 na to 1,000 amp or more, 0.1 mv to over 500v. Power relay is rated at 5 amp and power requirement is 15 watts. *Assembly Products Inc., Chesterland, Ohio*

Circle No. 29 on reply card

NEW PRODUCTS

GAGES STATICS and dynamics in violent systems.

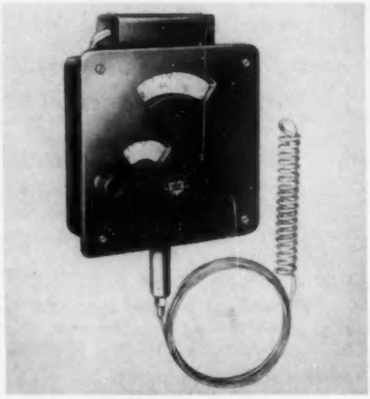
This compact unit has its own built-in power supply and will accept the input from pressure pickups at up to 75,000 psi under, the maker says, the most adverse conditions of temperature and vibration. It appears highly useful for pressure studies in rocket and jet motors, as well as hydraulic and explosive systems.

Characteristics

Output. . stable within 15 v into a high impedance load
Freq. Response. from 0 to over 20,000 cps
Cable lengths. . up to 1,000 ft if desired

Photocon Research Products, 421 N. Foothill Blvd., Pasadena 8, Calif.

Circle No. 30 on reply card



SLIP-IN THERMAL systems keep it on the job.

Production quantity calibrated thermal systems are available to slip into this controller to keep it on its job. It features a 12 in. rotating scale to eliminate parallax in control point setting. Ranges are available with a 300 to 550 deg span from minus 150 to 650 deg F. On-off electric contact control differential can be set as close

as 0.5 deg. Standard electrical rating is 15 amp at 115/230 vac. *United Electric Controls Co., 85 School Street, Watertown 72, Mass.*

Circle No. 31 on reply card

CONTROLLER with simplified contact action.

The maker of this indicating contact controller does not tell us how it does it, but the unit gives high-limit and low-limit signals at the set point without employing magnetic or locking coil action. It is also claimed that this apparently simple instrument can be used as a continuous control with automatic reset. Furnished with portable use or wall and panel mounting. *Larson Instrument Co., 24 Orchard St., Tarrytown, N. Y.*

Circle No. 32 on reply card

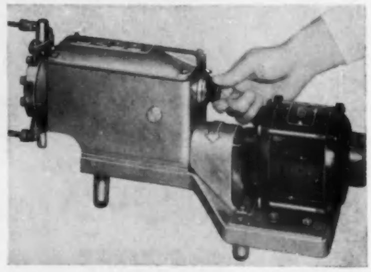
THERMOCOUPLE heads in polished chrome cases.

These thermocouple heads are only 1⅛ diam. Watertight, chrome-finished and operating in temperatures up to 200 deg F, they accommodate wire from 30 to 14 gage. *Conax Corp., 4515 Main St., Buffalo 12, N. Y.*

Circle No. 33 on reply card

NEW PRODUCTS

IDEAS IN FLOW



PUMPS OVER 1,000 shades of infinitely small.

In the picture a hand is setting a dial indicator that has 1,000 calibrated increments. This actually permits the output of the metering and proportioning pump to vary over this many increments in a range of from 0 to 2,400 mp of liquor per hour—literally from a controlled dribble to a precise trickle. A hydraulically balanced diaphragm isolated the liquid from pumping parts, and a standard 1/20 hp motor powers the stroking piston. Pumping rate—established by length of the piston stroke—can be dialed while the pump is either idling or operating. *Lapp Insulator Co., Le Roy, N. Y.*

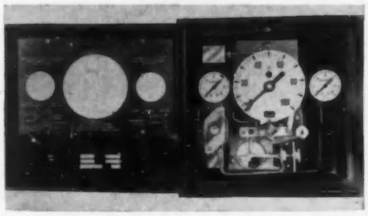
Circle No. 34 on reply card

FLOWING SOLIDS weighed while routed to carts.

The first application for this new strain-gage-actuated platform scale is the continuous weighing and control of flowing powdered materials into hopper carts. The cell itself can take up to a 500 lb load, has a 10 in. sq.

platform face, and fits into a 12 in.-deep recess. Indicating and control instruments can be mounted at a central remote location and routing of the flowing material into desired receptacles and to desired end-quantities can be controlled by selection and actuating devices. *Baldwin-Lima-Hamilton Corp., Philadelphia 42, Pa.*

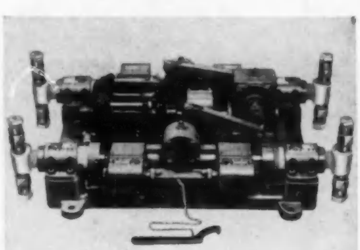
Circle No. 35 on reply card



PRESSURE PILOT is handily self-contained.

A good deal of thought went into making this new pressure pilot easy to adjust and versatile to apply. For example, it offers the full range of control operations—changing from proportional to differential gap control or from direct to reverse action involves simply slicking the current-type nozzle to pre-set positions. Further, both control modes can be dialed in over a 0-100 range. Other features: an all metal relay; pneumatic feedback synchronization; a saphire feed orifice with push-button cleaner. The unit mounts on the company's line of diaphragm control valves, but also is available separately. *Kieley & Mueller, Inc., 194 Genung Street, Middletown, N. Y.*

Circle No. 36 on reply card



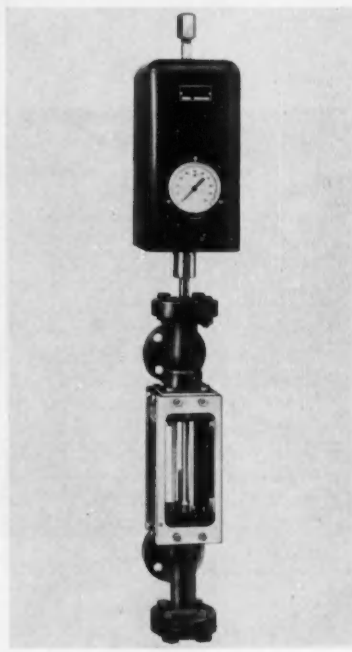
PLASTIC PARTS prolong proportioning pumps.

Use of unplasticized polyvinyl chloride or Kel-F in pump body and check-valve assemblies—also ceramic plungers and check ball valves—make these proportioning pumps quite immune to the ravages of corrosive fluids such as

NEW PRODUCTS

HCl, HF, HNO_3, $CuCl_2$ and $FeCl_3$. Capacities up to 19 gph per feed are available in one, two, three, and four feed units. Up to 300 psi pressures can be delivered. P.V.C. pumps can be used up to 150 deg F, while Kel-F units are useable up to 250 deg. F. The plastic parts are available also for converting existing "U" pumps. *Hills-McCanna Co., 3025 N. Western Ave., Chicago 18, Ill.*

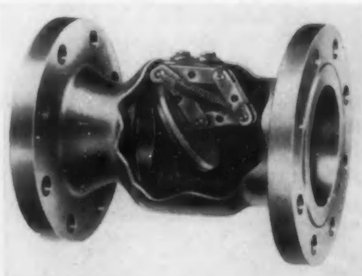
Circle No. 37 on reply card



ROTAMETER transmits with little movement.

Only three moving parts accomplish the pickup of float position and conversion to output air pressure in this new rotameter flow transmitter. The secret is a permanent magnet in the float extension. This proportionately attracts a flapper positioning armature in the transmitter. The movement of two air-loaded stainless steel pistons relative to the armature provides the restoring force to reposition the armature in response to flow changes. The resultant force-balance system has improved response and smaller air consumption. Also, with its low total float mass, the transmitter operates at flow rates as low as 0.5 gpm of water or 2.0 cfm of air. *Brooks Rotameter Co., Lansdale, Pa.*

Circle No. 38 on reply card



CHECK FLOW reverse before it begins.

Check valves are designed to permit free flow in one direction and to prevent return flow in the opposite direction—a problem in supply pipes to many processing systems. This unit cleverly does its job by anticipating the danger. As the picture shows, the seating flapper is suspended by a knuckle joint with spring action. Thus, spring tension on the flapper actually closes the valve before reverse flow occurs. The unit is rated for 150 psi and is available in various bodies and in 4, 6, and 8 in. sizes. W. R. Ames Co., 150 *Hooper Street, San Francisco, Calif.*

Circle No. 39 on reply card

PILOT MATES neatly with this valve.

Here is "erector-set" construction for heating-control closed-loop systems. The makers of this solenoid valve have equipped it with a control socket receptacle so that any one of a variety of thermal or pilot pickups can be mated to it. Further, the pilot includes a rugged snap-action switch and is available with either automatic reset or manual reset. The valves come in ½, ¾ and 1 in. sizes and standard power requirements are 25v or 115v 60 cycle. Altogether, it should be easy to work up combinations to control just about any gas burning setup. White-Rodgers Electric Co., 1209 *Cass Ave., St. Louis 6, Mo.*

Circle No. 40 on reply card

PROGRESS IN POTS

SWITCH in pot turns two turns to ten.

Something here is new in pots, really original. When you finish the single turn of this potentiometer's shaft instead of stopping against ordinary stops, you're pressing against the rotor of a ten-position switch. Precision-fixed resistors wired to this attenuator switch in combination to the single-turn section, provide resolution equivalent to 10 turns of a conventional pot. Its size: $1\frac{3}{4}$ in. diam, by $1\frac{3}{4}$ in length. *Electro-Measurements, Inc., 4312 S. E. Stark St., Portland 15, Ore.*

Circle No. 41 on reply card

LINIPOT converts inches to ohms for the traveler.

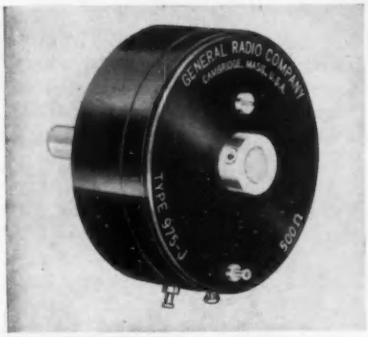
Got anything slipping around? For four full inches this wire-wound pot will trade resistance for distance. With resolution better than 0.001 in, you can't be very far off when this is used

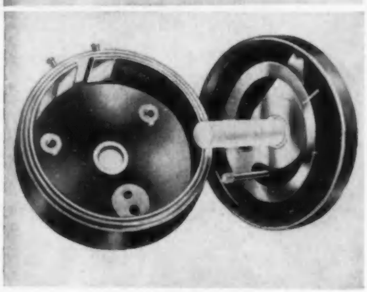
in a position-indicating setup. The shaft rotates freely, and up to four windings can be used with it. *Benson Lehner Corp., 2340 Sawtelle Blvd., Los Angeles 64, Calif.*

Characteristics

Friction	1 oz
Resistance range	50 to 50,000 ohms
Life	1 million cycles
Linearity	plus or minus 0.05 per cent

Circle No. 42 on reply card

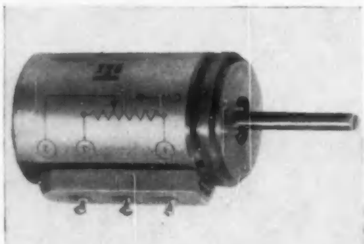




LOW-COST at no cost to quality.

At prices under $10, General Radio offers a series of pots packed with all the stuff good pots are made of. Linearities start at plus or minus 0.2 per cent. *General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.*

Circle No. 43 on reply card



TINY POT would fit vest-pocket computer

Here's another part for that vest-pocket computer: a ¾ in. diam 10-turn potentiometer with superb linearity. For the color-conscious engineer, the

fully-shielded housing is red anodized aluminum. High resolution, low torque, long life are among its features. For those who want something distinctive, taps will be provided within plus or minus 1 deg. The turret terminals are gold-flashed silver. Ask for the "L1OS". *Technology Instrument Corp., 531 Main St., Acton, Mass.*

Characteristics

Size	$1\frac{3}{8}$ in. long, $\frac{3}{4}$ in. diam
Resistant range	1 to 100 k ohms
Linearity	0.05 per cent standard
Torque	0.75 oz-in., starting
Rating	5 watts at 40 deg C

Circle No. 44 on reply card

NO BLOW too beastly for these pressure pots.

Aircraft pressure potentiometers have suffered in the past from the fact that their natural frequencies were in the range of those of vibration and shock in flight. In developing a resistance winding of 1,200 turns to the inch, Transonics, Inc., was three years ago able to produce a pressure potentiometer with natural frequencies above 55 cps with vibrations of plus or minus 10 g. The trick was accomplished by using extremely strong high-rate springs. The advent of jet aircraft raised the vibration and shock situation to plus or minus 10 g at 500 cps.

Now, after two years of research, new Baroresistors can meet those specifications. Available for pressure ranges from 14 to 7 psi to 60 psi, they display an error of only plus or minus 2 per cent of full scale. Rated at 10 ma, they have 7,500 ohm windings. *Trans-Sonics, Inc., Bedford, Mass.*

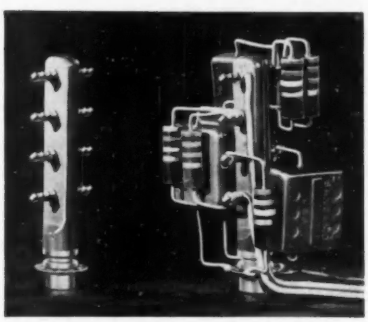
Circle No. 45 on reply card

ELECTRONICS ORIENTED

FREQUENCY RESPONSE seen with speed and ease.

Here's an FM oscillator with an ingenious objective: instantaneous frequency response curves. By generating a constant-amplitude output voltage continuously varying in frequency from 20 cps to 200 kc, or any part of that range, the oscillator can provide a scope face presentation of the frequency response of a piece of electrical gear passing the frequency on. The frequency sweep can be varied from 0.5 cps to 50 cps according to saw-tooth, triangular, or square wave forms. A frequency marker can be positioned to 0.1 per cent accuracy. The oscillator is called a swept-frequency generator, Model 200K. *Electromec, Inc., Burbank, Calif.*

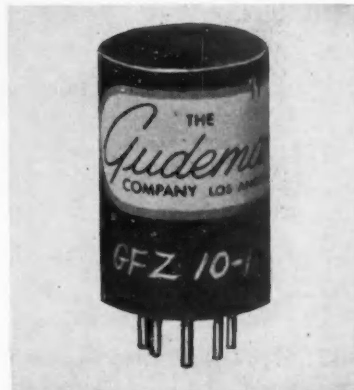
Circle No. 46 on reply card



UPRIGHT MOUNTS fit cramped quarters.

If you haven't printed all your circuits, potted all your parts, or painted all your components, here's a new twist for those old-fashioned resistors and capacitors. Some users, says Sangamo, save 5 ft of wire by putting one of these Tote-m-pole's to work. A single hole in your chassis provides for an insulated, easily-ventilated resting place for small parts. Enough Tote-m-poles and you need no chassis. *Sangamo Electric Co., Springfield, Ill.*

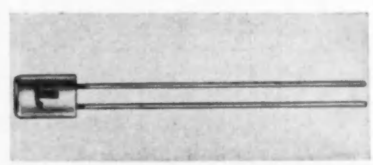
Circle No. 47 on reply card



MATCH-MAKING transformer passes 2 microsec pulses.

This Epoxy-cast product matches impedances of 1,000 ohms to 100 ohms to pass pulses as short as 2 microsec with less than 5 per cent tilt and overshoot. The GFZ 10-1 has a rise time of less than 0.07 microsec in a case 23/32 in. diam. *The Gudeman Co. of Calif., Inc.*, 9200 *Exposition Blvd., Los Angeles* 34, *Calif.*

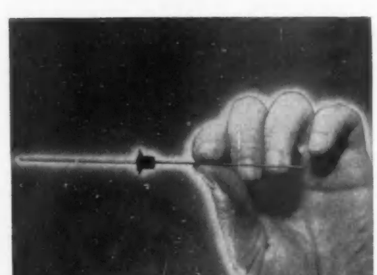
Circle No. 48 on reply card



SILICON DIODES are stable and efficient.

Here's a fine new crew of silicon diodes. They pay no heed to heat or age. A sharp Zener break makes for stable voltages. They are 98 per cent efficient. Some mount with screws for conduction cooling. *Transitron Electronic Corp., Melrose* 76, *Mass.*

Circle No. 49 on reply card



DIODES by the dozen for doughty duty.

Although the advertising claims that

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(57) RANGE SERVOS. Servomechanisms Inc. This 32-page booklet amuses while it instructs. Some mighty colorful cartoons tell about the company's new line of servo components for coupling radar to guns. Includes lucid function definitions, block diagrams, and Petty-girl analogies.

(58) COMBINATION VALVE, STRAINER, AND FLOW RATE CONTROL. Hays Manufacturing Co. Folder No. 215, 12 pp. The innards are described and pages of performance data tabled on the versatile "Electro-Mitc" valve.

(59) AIR CYLINDERS. The Bellows Co. Bulletin CL-50. Here are 36 handsome pages of bona-fide engineering information on the company's complete line of air actuating devices. Applications are detailed particularly well.

(60) R & D FACILITIES. Lear Inc. Twenty-five pages—with very little space waste—detail who Lear people are, where they work, what they work with, and what they can do for you.

(61) TOTALLY PROTECTED MOTORS. Reliance Electric and Engineering Co. Exactly 100 positive virtues of this new ac. motor line are spelled out in this lively 12-page booklet.

(62) AIR CAPACITORS. Allen D. Cardwell Co. Capacitor Catalog No. 823. Mechanical and electrical specifications on the company's line of air capacitors.

(63) ENGINEER'S CHECK LIST. B-I-F Industries, Inc. B-I-F M-3. If you have anything to do with water treatment you'll want this convenient check list on the many types of instruments and controls you can apply.

(64) MYLAR DEVELOPMENTS. E. I. duPont de Nemours & Co. The second edition of a booklet full of application know-how for "mylar" polyester film. Good information on insulation use in control components.

(65) FLOW CONTROL DATA SHEETS. Milton Roy Co. Three new one-page application data sheets describe interesting pump-controlled flow systems for natural gas lines, cement beneficiation, edible oil processing. No.'s E-54-7, E-54-2, E-54-1.

(66) RECORDER CHARTS. Technical Charts Inc., A 12-page packet that includes actual samples of both circular and strip charts—from 3 to 12 in. widths and diameters.

(67) INDICATING CONTROLLER. Fenwal, Inc. A one-page bulletin offering characteristics and application data on the company's new low-cost remote bulb indicating temperature controller. Brochure MC-122.

(68) SIMULATORS. Link Aviation, Inc. Four-page folder, that describes the what, where, how, and why of aircraft flight simulators.

(69) NEW INSTRUMENT DOSSIER. Leeds & Northrup Co. Five fully detailed data sheets describe the company's new line of "Speedomax" Type H instruments. They tell which unit to pick for varied applications too.

(70) CENCO NEWS—NO. 80. Central Scientific Co. The latest issue of this excellent house organ has a fine basic article on the selection of instrument according to information desired.

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(71) CHICAGO FOR THE SOCIETIES? ASCE, ASME, AIEE, AIMME, ASCE. This emphatic 24-page brochure tells why the engineering societies would benefit by moving from their present New York headquarters to Chicago.

(72) AUTOMATION–IN SECTIONS. The Cross Company. A 15-page booklet that describes the company's interesting system of dividing machines into sections, which permit units shut-downs without disturbing full production.

(73) TEMPERATURE TRANSMITTER. Moore Products Co. A very understandable functional diagram opens this seven-page bulletin (No. 3302), which exposes all facets of a new null-balance thermometer transmitter.

(74) REGISTRATION CONTROL. Photoswitch Div., Electronics Corp. of America. Bulletin PD 551 describes a registration control that responds to roll speeds from 15 to more than 500 ft per min.

(75) PNEUMATIC TRANSMITTER. Builders-Providence, Inc. Four-page folder unveiling the design and application of a new, low-cost pneumatic transmitter for rate of flow, loss of head, and liquid level measurement.

(76) INDICATING TEMPERATURE CONTROLLER. United Electric Controls Co. This 6-page brochure (Bulletin 42) offers engineering data and suggests uses for a newly developed temperature indicator with electric control.

(77) POTENTIOMETERS. Computer Instruments Co. Four sheets describe nine different pots and pot parts. Dimensions and complete characteristics are provided in detail.

(78) PROGRAMONITOR. Counter and Control Corp. Bulletin 505, 8 pp. Information on the construction and operation of a versatile mechanism for counting shaft revolutions or electrical pulses through a solenoid, and actuating switch sequences accordingly.

(79) MOTOR CONTROLS. Furnas Electric Co. Booklet 5411, 48 pp. This pocket-sized booklet is crammed with information on motor control switches, pressure switches, magnetic starters, push buttons, and foot switches with photographs.

(80) VIBRATING REED AMPLIFIER. Applied Physics Corp. Bulletin P45 deals with the operation of an amplifier for very weak dc currents, as found with mass spectrometers, insulator, semi-conductor, photo-electric, and similar research.

(81) CONNECTORS. Cannon Electric Co. DP9 Bulletin 64 pp. A thick, luxurious sort of catalog of panel, rack, and chassis-type plugs. This takes in everything from the sub-miniatures on up.

(82) CONSTANT FLOW VALVE. Askania Regulator Co. Form 1-89, 2 pp. Data on the performance and applications of a flow valve accurate to 1 per cent with rates of up to 700 gallons per hour despite pressure fluctuations.

(83) JET PIPE PNEUMATIC RELAY. Askania Regulator Co. Form 1-88, 2 pp. Not only does this device position a hydraulic cylinder proportional to a 3-to-15-psi pneumatic signal, but it transmits a pneumatic piston-position feedback signal.

(84) HYDRAULIC CONTROL MANIFOLDS. Almo Tool Co. A 4-page folder describing a method of laminating metal plates with slots to obtain complicated hydraulic circuits in a strong, compact assembly.

(85) OSCILLOGRAPH. Offner Electronics Inc. Eight-page catalog talks about a rack-sized direct-writing oscillograph with frequency response up to 70 cps.

(86) SERVOS. Servo-Tek. Cat. No. 14, 36 pp. A complete line of servomotors, motor tachometers, synchros, and special transformers for use with grid-controlled rectifiers.

(87) VERTICAL MOTORS. U. S. Electrical Motors, Inc. Bulletin No. 1868 describes solid-shaft vertical-mounting motors from ½ to 400 hp. Single phase types from 2 to 7½ hp also are marketed.

(88) INSTRUMENTS, MOTORS, AND CONTROLLERS. AEG, Frankfurt. General catalog, 91 pp. A complete line of motors, motor controllers, voltmeters, recording voltmeters, etc.

(89) V-DRIVES. Browning Mfg. Co. Bulletin 2098, 4 pp. Describes a multiple V-belt moulded into a single unit. Said to combine the advantages of both V-belts and flat belts.

(90) PRECISION FACILITIES. Avien. Sixteen-page bulletin of facilities available for precision military or civilian instrument manufacturing and assembly.

(91) GROOVE GAGE. Mueller Laboratory. Folder, 6 pp., describing pistol-grip gage for measuring "O" ring and snap ring grooves. Measurement range is from 0.187 to 2.250 in.

(92) RESISTOR WINDER. Geo. Stevens Mfg. Co., Inc. Three-page specification sheet for bobbin and resistor winder. Coils of up to 4 in. diam and 15 in. long are acceptable.

these diodes increase the practicability of guided missiles, we feel that they may nevertheless be put to other uses. Silicon being the magic substance in the, temperatures of up to 200 deg C make no matter. With a 2 v forward drop, and a 100- to 500-milliamp rating, voltages of from 50 to 500 are held up. *Bogue Electric Mfg. Co., Paterson, N. J.*

Circle No. 50 on reply card

POWER SUPPLY offers wide voltage range.

This power supply provides a range of 0 to 300 v while delivering 0 to 75 milliamp. Held stable to 0.1 v for both line fluctuations and load variations, it provides also a filament supply of 6.3 v at 10 amp, center tapped. Really two dc supplies with individually-adjustable ranges through 0 to 150 v, with a ripple of less than 3 milliv, the 300 v tops can be had by putting both supplies in series. *Kepco Laboratories, 131-38 Sanford Ave., Flushing 55, N. Y.*

Circle No. 51 on reply card

an ALARMING error

We must have been seeing blinking lights when we wrote item No. 38 in March New Products. First off, there are no cards in Panalarm's new annunciator. The warning shows up on an illuminated plastic nameplate. Second, the light doesn't continue to flash after the operator presses the button —it becomes steady until the condition is corrected. Third, we went and misspelled Panalarm in the address. Three strikes and we could be out.

PREVIEW of the "DIVIAC"

We got news of this hot new item just a bit too late for this month's New Products Section. Its a device which its maker—Feedback Controls, Inc. Alexandria, Va.—claims will "automatically perform the functions of a Kelvin-Varley circuit". It looks like a pot, but has absolute zero based linearity and may be well worth a letter to the maker before our May issue.

WHAT'S NEW ABSTRACTS

Sure Cure for Jitters

From "Jitter in Instrument Servos," by R. L. Hovious, Goodyear Aircraft Corp., Akron, Ohio. "Applications and industry," (AIEE), January 1955

Jitter is unwanted noise of a predominantly oscillatory nature. It can be wide-band, or it can contain only one or two frequencies. Mathematical analysis by itself can be inconclusive and misleading, because jitter has many origins and takes many forms. Analysis by analog computer simulation along with analytical methods, however, permits successful investigation.

The methods used in this study included:

▶ Simulation of a suppressed-carrier servo, including the important nonlinearities and noises.
▶ Application of the describing function technique to supplement and guide the analog computer simulation.
▶ Measurements made on a specific servomechanism.

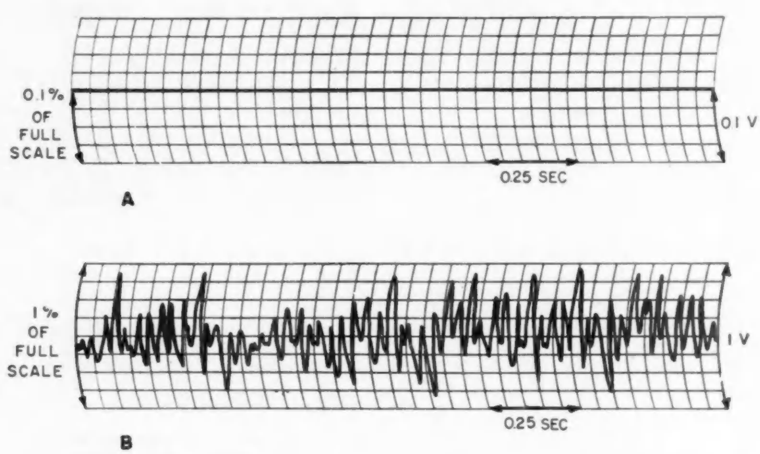
The paper describes the results of the study, not the techniques used. It identifies some unreported causes of jitter, and the jitter-causing nonlinearities that can be eliminated. The paper also establishes some relations between unavoidable non-linearities that will eliminate jitter, expressing the effects of granular or quantizing elements mathematically and proving the validity of these equations. The principles were used to modify a commercial servo with remarkable results.

Conditionally stable systems were not studied.

The most important system-generated noise was caused by the static dc unbalance between the tubes in the push-pull output stage of the servo amplifier. This noise signal flowed through the two-phase motor control winding. Interaction with the 60-cps reference winding voltage produced a strong 60-cycle torque which produced a 60-cycle servo output voltage at zero-signal input. The motor and gear inertia and viscous friction were not sufficient to damp out all this torque.

Also studied and reported upon were the effects of granularity, such as the step-shaped output caused by the finite resolution of wire-wound potentiometers. Other causes of jitters include: gear backlash, and the effects of coulomb friction; wiper-arm contact noises; amplifier pickup noise; and vibrator, or chopper, noise. The remedies or palliatives are indicated for all of these common ailments.

The wiper-arm contact noises mentioned are due to varying contact resistance from wire to wire, and to bouncing at high wiper-arm speeds.



(A). Output noise in servomechanism after modifications

(B). Output noise in servomechanism before modifications

For Multiplying Voltages

From "Two New Electronic Analog Multipliers," by Maurice A. Meyer and Harrison W. Fuller, Laboratory for Electronics, Inc. "Review of Scientific Instruments," December 1954

Two four-quadrant, all-electronic multipliers are described that are believed to be new methods of multiplying two time functions. Both multipliers use balanced modulators as basic circuit elements in similar interconnections and auxiliary circuits, although the operating principles of the two circuits are quite distinct.

The first described is a modified double-amplitude modulation scheme using two fixed and different carrier frequencies, which lends itself easily to a high degree of stabilization. The test multiplier has a frequency response from dc to 30 kc for either input. Maximum error is plus or minus 0.5 per cent of full scale at full-scale output, and plus or minus 0.2 per cent of full scale at one-tenth of full-scale output. The dc drift stability is plus or minus 0.15 per cent of full scale, and the scale factor stability is plus or minus 1 per cent of full scale over a period of several hours.

The second multiplier is a successive amplitude-modulation and phase-modulation scheme requiring only a single fixed-frequency carrier, but it is not so easily dc-stabilized as the first. The performance of this second multiplier is, in general, inferior to the first.

The article describes a diode-bridge balanced modulator necessary for both designs, as well as the theory of operation of the multipliers and the possible sources of error.

A Simpler Sampler

From "Proportional Liquid Sampler," by John M. Ruddy, Architectural Planning Division, Brookhaven National Laboratory, Upton, N. Y. "Nucleonics," February 1955

An extremely simple float-actuated sample dipper was designed and installed in a self-syphoning tank on the effluent line of a chemical laboratory hot cell. The sampler is a 100-cc dipper on one end of a hollow line with a float on the opposite and heavier side.

As the tank fills, the float rises, pushing the dipper under the surface

and filling it. The tank self-syphons upon filling, and the heavier float end raises the dipper discharging the collected sample through the hollow shaft and hollow arm to a sampling container for analysis.

This sampler is accurate to plus or minus 5 per cent for effluent flows between 0 and 10 gal per min. It is completely self-powered, foolproof, and has a very low (under $200) initial installation cost.

Rasing the Boundaries

From "Single-Crystal Germanium," by H. E. Bridgers, Bell Telephone Laboratories, "Bell Laboratories Record," February 1955

Germanium used in the first crystal rectifiers and transistors was polycrystalline. Each small crystal in a polycrystalline material is a regular array of atoms. Although the pattern is identical in each crystal, the relative orientations are different. For this reason, the pattern does not match where two crystals join, and a grain boundary results.

These grain boundaries seriously affect the electrical properties of the material. Their presence was one cause of the erratic behavior of the galena crystals used in early radio detection. Germanium and silicon rectifiers have been mass-produced from material from which these grain boundaries had not been totally eliminated. But reliable operation of the transistor made it imperative to get large single crystals of germanium.

Large single crystals were first grown by Gordon K. Teal (now director of research for Texas Instruments, Inc.) and his associates in the chemical physics department. Zone-purified germanium is melted (about 1,700 deg. F) by RF induction heating in a carbon crucible. The crucible is enclosed in a quartz tube that confines a flow of hydrogen gas.

The hydrogen provides an inert atmosphere and serves also as a cooling medium. Rapid temperature control requires adequate cooling plus readily available power.

A small single-crystal "seed" of germanium, supported by a shaft that extends into the system, dips into the melt. As the shaft is slowly withdrawn the seed grows in diameter, and a large single crystal is produced. The crystal grows at the interface between crystal

and melt. Crystal diameter depends on the crucible temperature and the rate of withdrawal.

Shades of Shannon

From "The Significance of Information Theory to Communication Systems," By R. F. Rous and R. F. B. Speed, Research Laboratories of the General Electric Co. Ltd., Wembley, England. "Communications and Electronics," February 1955, London.

One of the most important practical uses of information theory to-date has been investigation of the relative efficiency of the many known methods of information transmission. Also important, it can suggest reasons for the shortcomings of some systems and, hence, possible ways to improve them.

This is a well-written, non-mathematical exposé of information theory: what it is, and its contributions to our understanding of transmission systems. The article reflects some of the enlightenment shed by the theory on such subjects as the efficient use of channel space and the power required for information transmission. Bandwidth requirements, pulse and pulse-code modulation, and signal and noise separation are some other items reviewed in the new light.

The authors, rather than speculate on the possibilities, choose to conclude by remarking on some of the tendencies in present-day transmission systems. The trends toward higher and higher carrier frequencies, where bandwith requirements impose less of a problem, is balanced by the disadvantage that reception is reliable only over relatively short distances.

Improved components have made possible transmission of 1,800 channels in an 8-megacycle bandwidth on a single coaxial cable.

Information theory may offer more help as engineers try it further.

FEEDBACK FACT

Posed: Feedback control for the hasty or hesitant orator.

Solved: As the speech unrolls below the orator in his lectern, a palm-held control, in this Tele Q Corp system, synchronizes its unfurling with verbal velocity.

NEW BOOKS

For the Man First

HUMAN ENGINEERING GUIDE FOR EQUIPMENT DESIGNERS. Wesley E. Woodson, *U. S. Navy Electronics Laboratory, San Diego, 8 by 10½ in., 245 pp. Published by University of California Press, Berkeley 4, Calif.* $3.50.

"Equipment" in this case can mean anything from a radar console to a typing table, from a hand-hole to a passageway, from the best switch-handle to normal-indication pointer positions for multiple instrument combinations.

Even if the only "equipment" you ever design are some shelves in your basement, this book is worth its price for the pains in the neck it will save you. For the engineer, it is an invaluable compilation of facts and figures on the measurements, abilities and limitations of the human body.

Although control engineers are striving to free the man from systems, he is still very much a part of most of them. He is human; engineers should be humane.

The successful design of equipment for human use requires consideration of some basic human characteristics. Sensory capacities, mobility and muscle strength, intellectual abilities, common skills and capacity for learning new skills, capacity for team or group effort, and body dimensions—all are important characteristics. And the effects of working environment on human performance may be important.

The volume relies as much on illustration as on text, and is illumined with a great number of line drawings, which are often as amusing as they are enlightening.

The book has five major segments, titled: "Design of Equipment and Workspace", "Vision"; "Audition"; "Body Measurement"; and "Other Factors". An indication of thoroughness may be had by breakdown of the chapter on vision. Some of the items covered include: structure of the eye; functions of the eye, light accommodation, convergence, saccadic movement, visual field, characteristics of rods and cones, intensity relationships, acuity, other features of seeing like summation and interaction, stereoscopy, single and double images, apparent motion, optical illusions, afterimages, factors that make seeing easier, color, its sensitivity zones, formation, trichromatic system, aesthetics of color, color abnormalities, and psycho-

physical relationships. All this is followed by a reference list of nineteen important works on various aspects of human vision.

The "Other Factors" chapter, if you are wondering, includes things like taste, smell, hunger, and thirst. Neuron excitation, reflex activity, reaction time, motor performance on specific tasks, and principles of motion economy are also covered. Body sway, perception of vertical, and absence of gravity are discussed.

All these things give only an inkling of the thoroughness of this handbook on human characteristics.

Toward Tubeless Electronics

TRANSISTORS: THEORY AND APPLICATIONS. *Abraham Coblenz, Transistor Products, Inc., and Harry L. Owens, Signal Corps Engineering Laboratories,* 6 by 9 in., 313 pp. *Published by McGraw-Hill Book Company, Inc.,* 330 W. 42d Street, New York 36, N. Y. $6.00.

Transistor theory in simple language was apparently the aim of the authors. And they have succeeded. The mathematical theory is uncovered only after a good intuitive foundation has been laid—and then its intention is the practical application of transistors.

This book is essentially the eleven articles published in "Electronics" magazine from March, 1953, until January, 1954. These articles, expanded and revised, form eleven chapters of the book, which opens with a short history of transistors.

Three new chapters have been added. These deal particularly with manufacturing processes, silicon transistors, and a variety of special topics, such as the uni-polar field-effect transistor, and photoelectric effects.

Chapter titles based on the "Electronics" series are indicative of content: "Holes and the Transistor;" "A Glimpse of Quantum Mechanics;" "The Electron;" "Nature of Semiconductors;" "Point Contact Transistors;" "Junction Transistors;" "Electronics of Transistors;" "Small-Signal Parameters;" "Grounded Emitter and Grounded Collector Connections;" "Theory of Transistor Switching Circuits;" and "Cascading of Transistors".

Transistors are already finding their way into some control systems, and will unquestionably prove the answer for some of the problems now "impossible" to solve. If you want to learn about transistors and their possibili-

ties, there is probably no easier way than this book. It goes far enough for most people, too.

AC From the Beginning

Alternating-Current and Transient Circuit Analysis. *Harris A. Thompson, Associate Professor of Electrical Engineering, University of Colorado, 6 by 9 in., 317 pp. Published by McGraw-Hill Book Company, Inc., 330 W. 42d Street, New York 36, N. Y. $6.75.*

Here is a new undergraduate text introducing the fundamentals of steady-state ac circuit analysis and transient analysis.

Transient analysis development is the typical introduction to classical methods. The chapter on transient analysis is placed toward the end of the undergraduate curriculum.

Topics covered include: elementary circuit theory; definitions; complex algebra and phasors; current, voltage, power, and energy relations; use of phasors in steady-state analysis; special aids in circuit analysis, such as superposition, constant-voltage, and constant-current sources, etc.; three-phase circuit analysis; non-sinusoidal periodic waves (and Fourier series); classical transient analysis; and a short introduction to electromechanical analogs.

Control Compiled

Automatic Control Bibliography. *Warren F. Wade, graduate student, MIT, and Emory N. Kemler, professor of mechanical engineering, University of Minnesota, 6½ by 8½ in., 331 pp. Published by Summary Reports, P. O. Box 176, Spring Park, Minn.*

The authors of this book have done a commendable job of summarizing the important American and English works on control written since 1900.

The short abstracts appended to the listings are a great help. These abstracts do not evaluate the articles, but do convey the content properly where the article title fails to do so.

This bibliography of 1,623 articles is arranged alphabetically by authors, and alphabetically by magazines for those articles where no author was shown on the original.

The bibliography is not completely classified because of the overlapping of subject matter in the various fields of application.

WHAT'S AHEAD: MEETINGS

MARCH

Institute of Radio Engineers, National Convention, Waldorf-Astoria and Kingsbridge Armory, New York, N. Y. Mar. 21-24

American Institute of Electrical Engineers, Materials Handling Conference, Hotel Cleveland, Cleveland, Ohio. Mar. 28-29

American Society of Metals, Ninth Western Metal Congress and Exposition, Ambassador Hotel and Pan American Auditorium, Los Angeles, Calif. Mar. 28-Apr. 1

APRIL

American Institute of Electrical Engineers, Southern District Meeting, St. Petersburg, Fla. Apr. 13-15

American Society of Mechanical Engineers, Diamond Jubilee Spring Meeting, Lord Baltimore Hotel, Baltimore, Md. Apr. 18-22

Society of Automotive Engineers, Golden Anniversary Aeronautic Meeting, Aeronautics Production Forum, and Aircraft Engineering Display, Hotel Statler and Hotel McAlpin, New York, N. Y. Apr. 18-21

Scientific Apparatus Makers Association, 37th annual meeting, The Greenbrier, White Sulphur Springs, W. Va. Apr. 24-28

MAY

American Institute of Electrical Engineers, Middle Eastern District Meeting, Columbus, Ohio. May 4-6

American Institute of Electrical Engineers, Electric Heating Conference. LaSalle Hotel, Chicago, Ill. May 10-11

Engineering Symposium – Michigan State College, "Automation-Engineering for Tomorrow," Michigan State College, East Lansing, Mich. May 12-14

American Institute of Electrical Engineers, National Telemetering Conference, Hotel Morrison, Chicago, Ill. May 18-20

JUNE

Human Engineering Institute, Course in Human Engineering, Dunlap and Associates, Inc., Stamford, Conn. June 6-10

American Institute of Electrical Engineers, Summer General Meeting, New Ocean House, Swampscott, Mass. June 27-July 1

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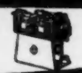
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Double contact with Solenoid Reset; Sensitivity 7.5 Microamps; Reset coil 6-24 VDC or 24 VAC; Makes contact on increasing or decreasing values; Contacts; "Twintacts", Capacity 100 ma at 110 volts; Nickel plated. Brass cover; Weston Model 705 Type 6 #R560 ....**18.75; 10 for 170.00**

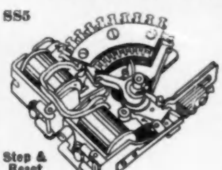
Same as #R560 but with glass face; Weston Model 705 Type 6 #R561.**19.75; 10 for 180.00**

Single contact (Normally Open), Solenoid Reset; Sensitivity; 10 Microamperes; Reset coil; 6-24 V DC or 24 V AC; Contact: "Twintact", capacity 100 ma at 110 volts; Glass Face; Weston Model 705 Type 4 #R523.**17.75**
10 for 160.00

Same as #R523 with Brass Cover Weston Model 705 Type 4 #R523N............**16.75**
10 for 150.00

STEPPING SWITCHES

SS5


Step & Reset

Mfg by Western Electric, Automatic Electric Sales
Minor Switch
10 steps and off
Contacts: Gold plated brass; BridgingWiper;
Operating Voltage 6.0 to 12.0 V. DC
Net Wt. 1 lb.

	Each	Lots of 10
#R960; Single Level; 6 to 12 VDC	10.95	9.00
#R975; Single Level; 24 to 36 VDC	11.95	10.00
#R976; Single Level; 48 to 60 VDC	12.95	11.00
#R977; Two Level; 6 to 12 VDC	12.95	11.00
#R978; Two Level; 24 to 36 VDC	13.95	12.00
#R979; Two Level; 48 to 60 VDC	14.95	13.00

SS6 Mfg. by Western Electric Co.; 22 step; 5 levels; Bridging Wipers; Contacts: Gold plated brass. Interrupter Switch: 1 Break-Make; Net Weight: 2 lb. 2 oz.

"Homing" Type; Double-Ended Wipers; Step in One Direction

#R926; 6 to 12 VDC	14.75	12.00
#R980; 24 to 36 VDC	15.75	13.00
#R981; 48 to 60 VDC	16.75	14.00

SS7 Mfg. by Western Electric Co.; 44 step; 2 levels; Bridging Wipers; Contacts: Gold plated brass; Interrupter Switch; 1 Break-Make; Net Weight 1 lb. 14 oz.

"Homing" Type; Double-Ended Wipers; Step in One Direction

#R927; 6 to 12 VDC	14.75	12.00
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#R983; 48 to 60 VDC	16.75	14.00

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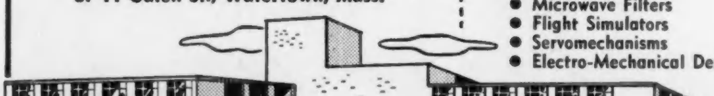

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Face up to AUTOMATION

let's take a few minutes to remove any mental block preventing you from a basic appreciation of the new concepts of data reduction and automation. Already you achieve an unbelievable amount of data processing in your own personal life: you combine information concerning your income, your required expenditures, the age and physical state of your car, your wife's feelings about style . . . and you process these data mentally to conclude that you will or will not buy a new car. The answer is not straight-forward, but it has its logic.

Similarly, data handling systems and data reduction systems supply *automatically* a humanly-determined logic to various pieces of information, and arrive at the compact answer which you—the process or manufacturing supervisor—feel is most important. You used to look at the information given by a heterogeneous collection of instruments measuring temperature, pressure, flow rates, tank levels, et cetera, and mentally decide whether or not the process was performing up to par: generally no one temperature or pressure or tank level was sufficient information. Nowadays, data handling systems can automatically "look" at these process variables for you, interpret them, and tell you *directly* whether or not the process is up to par—and if it isn't, the data handling systems can usually be made to tell you very specifically what to do to correct the inefficiencies.

You supply the logic

All that the data handling systems are doing, therefore, is automatically and consistently applying your logic to the available information from process or manufacturing operation to give you unhestitatingly—and directly—the specific answer you demand.

So much for data handling, data processing, or data reduction. Let's see if we can determine where the *automation* comes in.

Normally speaking, once you have analyzed the state of the process—either by evaluating the variables humanly, or by relying on an automatic data handling system—you must decide whether corrective action is necessary or whether the process is going along satisfactorily. If you do apply corrective action—you do so according to a logic which you have determined by experience. Both the decision to apply corrective action and the specific correction applied are logically arrived at.

Here's where automation can enter the picture. If you set up a system of automatic devices—a computer, more or less—to carry out the *logic* of "decision making" and "correction initiating," you have an automated process.

Realize that systems of data reduction or of automation are based on cold logic—there is no magic about them. *You* have to establish the logic, furthermore, before such systems can be effected. The systems merely save you the time and effort of repeating the logical reasoning and physical corrective action over and over again.

When do these systems become feasible?

Many such systems have been operating for years in certain fields of research, process operation, and factory production. When any information collecting and logical processing become repetitive—and when logical decisions and actions also become repetitive—data reduction and automation systems are generally possible. A thorough analysis of time and effort saved—of increased efficiency—will reveal the economic feasibility of such systems.

Who can help you know when such systems are suited to your operation?

The Data Reduction and Automation Division of Fischer & Porter Company has engineers whose systems experience dates back to 1941. The practical know-how of these men has been recently demonstrated in the manufacture of the F&P Automatic Logger, the F&P Multiple Pressure Readout System, the several types of F&P Digi-Coder analog-to-digital converters, and other ready-made packaged systems suited to immediate installation in many processing or manufacturing plants. These men can help you analyze your specific needs.

So if you would like to talk facts and figures on data reduction and automation system for your particular operation, write or call the nearest F&P office now.

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